

FINAL REPORT

(NASA-CR-156837) LONG-TERM PROSPECTS FOR
DEVELOPMENTS IN SPACE: A SCENARIO APPROACH
Final Report (Hudson Inst., Inc.) 302 p
HC AC4/MF A01 CSCI 22A

N78-12110

g3/12 15099
Unclas

Long-Term Prospects For Developments in Space (A Scenario Approach)

William M. Brown & Herman Kahn

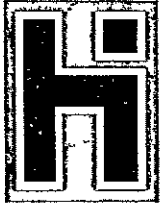
HI-2638-RR

October 30, 1977

PREPARED FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
UNDER CONTRACT NASW-2924

HUDSON INSTITUTE, INC.
QUAKER RIDGE ROAD
CROTON-ON-HUDSON
NEW YORK 10520





POLICY RESEARCH
IN THE PUBLIC INTEREST

Hudson Institute

CROTON - ON HUDSON, NEW YORK 10520

914-762-0700

TELEX 137343

November 16, 1977

NASA Scientific & Technical
Information Facility
P.O. Box 8757
Baltimore/Washington International
Airport
Baltimore, MD 21240

Contract No. NASW-2924
"Long-Term Prospects for Developments
in Space (A Scenario Approach)"
Final Report

With regard to the above referenced contract, please find herewith
enclosed three (3) reproducible copies of the final report.

Very truly yours,
HUDSON INSTITUTE

William M. Brown/aem

William M. Brown

WMB:aem

xc: Administrative Contracting Officer
(Code: JHC-1)

Enclosures: HI-2638-RR (3 copies)

HUDSON INSTITUTE

FINAL REPORT

LONG-TERM PROSPECTS
FOR DEVELOPMENTS IN SPACE
(A SCENARIO APPROACH)

By

William M. Brown and Herman Kahn

HI-2638-RR

October 30, 1977

Prepared for

National Aeronautics and Space Administration

Under Contract NASW-2924

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official opinion or policy of the National Aeronautics and Space Administration or of other agencies of the United States Government.

HUDSON INSTITUTE, INC.
Quaker Ridge Road
Croton-on-Hudson
New York 10520

ACKNOWLEDGMENTS

Much of the technological information on which this study is based was derived from existing NASA studies--especially the Outlook for Space and A Forecast of Space Technology, 1980-2000. We have also drawn freely from Arthur Clarke, Krafft Ehricke, Gerard O'Neill, Jesco von Puttkamer, and many others. We have benefited from critiques of prior drafts by numerous NASA personnel, especially Dennis E. Fielder, Robert F. Freitag, H. Hertzfeld, W. Ray Hook, C. C. Priest and Nathaniel B. Cohen, our industrious and helpful contract monitor. We also thank Herbert J. Rowe and the former administrator, James C. Fletcher, for their encouragement of a project which attempts a two-hundred-year perspective.

Perhaps the hardest part of this project was done by our assistants and support staff. In particular, the dedication of Maud Bonnell, Ann E. Marsek, Mary Mitchell and Elaine Shelah made the issuance of this report possible.

TABLE OF CONTENTS

ACKNOWLEDGMENTS	i
LIST OF FIGURES	v
LIST OF TABLES	vi
Chapter	
I. OVERVIEW, ORIENTATION, METHODOLOGY	
A. Introduction	1
B. Systematic Formulation of Space Scenarios.	7
C. Some Basic Political, Cultural and Social Contexts . . .	15
D. The 14 Contexts.	18
II. THE BASIC INTERNATIONAL CONTEXT	
A. Watersheds of History.	31
B. The Difference Space May Make.	35
C. The Basic Surprise-Free Earth-Centered Scenario. . . .	38
III. POTENTIAL 21ST CENTURY SPACE DEVELOPMENTS	
A. Some Early 21st Century Technologies	65
B. Space Industrialization (SI)	74
C. Other Commercial Opportunities	82
D. Future Space Program: Near Term	83
E. Future Space Program: Long Term	89
IV. OPTIMISTIC SCENARIO	
PART I: THE TRIUMPH OF THE MACHINE? (1976-2000)	
A. The Explosion of Technology.	107
B. The Early Space Program in the U.S.	108
C. The Earth-Centered Context	110
D. Improved Space Vehicles.	117
E. Space Industrialization.	119
F. Lunar Program.	122
G. First Tourists	124
H. International Cooperation.	126
I. The Space Culture.	128
J. Health in Space.	129
K. Spinoffs	131
L. Milestones	133
PART II: FIRST QUARTER--21ST CENTURY	
A. Economic Growth: A 100-Year Perspective	135
B. The Computer--Once More.	136
C. Space Developments	138
D. Life Science in the Space Environment.	144
E. Tourism.	146
F. Demilitarization	147

TABLE OF CONTENTS (Cont'd)

Chapter

IV. OPTIMISTIC SCENARIO (Cont'd)

PART III: REFLECTIONS ON THE HALF CENTURY
BEFORE THE TRICENTENNIAL

A. Maturity of Space Development.	150
B. Social and Economic Progress	151
C. Automation	152
D. Computers and Electronics.	153
E. Planetary Population	154
F. Space Vehicle Developments	156
G. Tourism.	157
H. Interstellar Exploration	158
I. Solar Civilization Government.	159

PART IV: FORECAST

A. Future Exploration	162
B. 100-Year Projections	166
C. A Universal Brain?	170

V. THE NEW INTERNATIONAL ORDERS

PART I: THE CHINESE SOLUTION
(A PESSIMISTIC SCENARIO--FROM NASA'S VIEWPOINT)

A. 1976-2000.	173
B. 2000-2025.	186
C. 2025-2076.	193

PART II: THE TRIUMPH OF THE GARDEN? (2025-2075)
(A WORLDWIDE PESSIMISTIC SPACE DEVELOPMENT SCENARIO) 202

Brazil	203
China.	204
The Perpetual Garden	208

VI. A MODERATE SCENARIO

PART I: SOME GOVERNMENT PERSPECTIVES

A. 1976-2000.	215
B. 2000-2025.	221
C. 2025-2076.	226

PART II: THE ROLE OF THE PRIVATE SECTOR

A. Spacecorp.	234
B. Space Industrialization.	235
C. Tourism.	236
D. Space Bufts, International	238
E. Solar Systems, Incorporated.	239

TABLE OF CONTENTS (Cont'd)

Chapter

VI. A MODERATE SCENARIO (Cont'd)

PART III: THE NEXT 100 YEARS (2076-2176) 247

VII. REVIEW AND ASSESSMENT

A. Images of the Future 257

B. Earth-Centered Perspective 259

C. Space Technology 262

D. The Scenarios. 265

E. Potential for Growth 270

LIST OF ACRONYMS. 275

BIBLIOGRAPHY. 277

Appendix

A. THE NEW CLASS. A-1

B. A MINI-SCENARIO IN WHICH THE LUNAR COMMAND BECOMES
THE MAJOR WAR-DETERRING ORGANIZATION B-1

C. THE PROBLEM OF WAR AND OTHER LARGE-SCALE VIOLENCE. C-1

LIST OF FIGURES

1. The Demographic Transition.	43
2. Gross World Product Per Capita, 1776-2176	62
3. Transportation Costs to Near-Earth Orbit.	81
4. Advanced Resources/Pollution Observatory (CO-1)	84
5. Coastal Anti-Collision Passive Radar (CO-9)	85
6. Atmospheric Temperature Profile Sounder (CO-11)	86
7. Personal Communications Wrist Radio (CC-9).	87
8. Space Tourists/Year	93
9. La Grange Points of the Earth-Moon System	99
10. NASA's Commercial Sales of Satellite Data	116

LIST OF TABLES

1. Surprise-Free Projection of World Population and GWP for the Basic 10/20/200 Scenario.	40
2. Estimates of World Energy Consumption	46
3. Resources of Principal Fossil Fuels	48
4. Relative Consumption of Important Industrial Metals (1968). . .	51
5. Potential for Increased Food Production	56
6. Some Early 21st Century Technologies.	66
7. Some Forecasts for Ultra Sensitive Sensors.	71
8. Progress in Space Technology, Past and Projected.	75
9. Ten Advantages of Operating in Space.	77
10. A Suggestive, But Hardly Exhaustive, List of Space Manufacturing Activities.	79
11. Applications Summary and Risk Estimation.	82
12. Keys to Long-Term Developments in Space	90
13. Projected Annual Investments and Production in Space.	96
14. Federal Budget 1961-1977.	109
15. Space Tugs in Operation or in Development Before 2000	120
16. U.S. Space Development Milestones	134
17. Optimistic Scenario, Population and Gross Product	167
18. Chinese Space Tourist Program	198
19. Highlights of U.S. Space Accomplishments, 1976-2000	217

Chapter I

OVERVIEW, ORIENTATION, METHODOLOGY

A. Introduction

The basic purpose of this report is to formulate some useful and interesting images of the long-term future of space, and to encourage and facilitate the use of such images and scenarios by NASA in its studies, planning, and public information programs. We realize that NASA already makes use of scenarios in its planning functions, but the deliberate formulation of long-term scenarios and "images of the future" has usually been left to outside freelance writers. We believe it is quite useful, perhaps important, for NASA to intervene in this process and also to facilitate it. Some of the current relatively low interest in NASA programs undoubtedly is due to the public's failure to understand how exciting space development can be in the medium term (1985-2000) as well as in the centuries beyond this one.

Of course, the extraordinarily extensive science fiction and other popular literature have already introduced a fairly broad public in this country and abroad to some concepts about space. This literature and its media interpretation however tend to be relatively undisciplined, imaginative (in both a good and bad sense) and, with a few important and spectacular exceptions, relatively unrelated to serious socio-political issues. We hope that this report will help to fill this last gap, particularly in relating current issues to potential NASA programs. The historical record shows that carefully developed medium- and long-term

images of the future have very often helped to place current priorities, problems, issues, or controversies into a more realistic and clearer context, and have provided useful perspectives for examining them.

Long-term scenarios about space development, and, even more important, shared images of the future of space, can contribute to a sense of community, of institutional meaning and purpose, of high morale, and even--to use somewhat extravagant terms--of manifest destiny or of "religious" mission. But it is important to achieve such goals in a way which is neither aggravating nor obnoxious. Appearing to be fanatical or seeking "pie in the sky" outcomes should also be avoided. To some degree such images, if expressed inappropriately or at inappropriate times and occasions, could create counterproductive impressions of this kind. In reality, however, such impressions are relatively rare, and, if they do occur, tend to be excused or dismissed rather readily. Since it is generally understood that any professional group tends to give itself a higher status and a more pervasive and important role than would outsiders, this tendency is considered acceptable and even respectable. Indeed, it is probably more appropriate for NASA than most other groups.

Such images can have a great impact on political issues--both internal and external.* In this regard, we believe that NASA might still try to exploit the legacy of the Bicentennial celebrations of 1976, which officially continue through 1989. This fact may help to provide a plausible and proper pretext for 100- or 200-year projections which are not narrowly focused on improving day-to-day planning or short-term programs.

*For a detailed discussion see Herman Kahn, "On Studying the Future," in Handbook of Political Science, Volume 7: Strategies of Inquiry, eds. Fred I. Greenstein and Nelson W. Polsby (Reading, Massachusetts: Addison-Wesley Publishing Company, 1975), pp. 405-442.

In this report we develop various scenarios from the vantage point of a space historian in the year 2077 or so looking back over "history." We do this, first, because it is a dramatic device but also because it conveniently places our discussions into a fruitful perspective. Our historian then attempts to project the "next 100 years in space." If NASA wished to exploit scenarios of this kind and related images of the future, it could begin with a conference (described below) in 1978, or later; this could be done under non-NASA auspices. To give a sense of what is meant the next page shows a format for a hypothetical two-day conference of this kind. The suggested talks, titles and speakers should not be taken literally; they are illustrative only, intended to provide an idea of what might be planned.

If such a meeting were held, we would hope that as a result of the activities associated with it, many medium- and long-run possibilities for space development would be described and elaborated upon in a dramatic and informative fashion. The audience would be both those who attend the meeting, and a much broader public which would be reached through the news media or any subsequent publications or presentations. The meeting might well result in a variety of useful materials, such as a book, pamphlets, films for schools and educational TV (and perhaps for a wider distribution), illustrated wall charts, and video tapes of some of the proceedings. Some of these might be made during the meeting and some as a follow-up; other information programs and various independent and semi-independent products might be stimulated by the conference or its ancillary activities. Alternatively, an initial meeting might be

THE "TRICENTENNIAL" CONFERENCE ON SPACE

Smithsonian Astrophysics Hall
Washington, D. C.
July 2080 (or so)

9:00 - 9:30 am	<i>Welcome</i>	
9:30 - 10:00	Demographic/Economic Context (Past, Present, Future)	Bell, Kahn, Rostow
10:00 - 11:00	The Early Beginnings (to 1980 - or so)	Krafft Ehricke or Thomas O. Paine
11:00 - 11:15	<i>Coffee</i>	
11:15 - 12:30 pm	Where We have Been (in retrospect, from 2080)	Fletcher or Frosch
12:30 - 2:00	<i>Lunch</i>	
2:00 - 3:45	Reports from Various Activities (e.g., lunar base, Mars base, L-5 colony)	Hearth, other NASA speakers
3:45 - 4:00	<i>Coffee</i>	
4:00 - 4:30	PANEL: Goals for the Future of Space Development	
4:30 - 6:00	PANEL DISCUSSION OF DAY'S SPEAKERS	

9:00 - 11:00 am	Alternative Social Histories (1980-2180)	Bell, Ferkiss, Gordon, Hitch, Kahn, Toffler, etc.
11:00 - 11:15	<i>Coffee</i>	
11:15 - 12:30 pm	Alternative Space Scenarios (1980-2180)	Frosch, Fletcher, Sagan, Ehricke, Taylor, Clarke, Berry, Jastrow, Dyson, Feinberg, Asimov, O'Neill, Brown and others
12:30 - 2:00	<i>Lunch</i>	
2:00 - 3:45	PANEL: Critique of the Two Days: Lessons for 1980	Three Speakers
3:45 - 4:00	<i>Coffee</i>	
4:00 - 5:30	Recapitulation and Benediction	Fletcher or Frosch

held exclusively for NASA's internal purposes. (The concept of holding such a conference is not touched upon in the body of this report.)

This report includes a number of ingredients which should be of special interest to anyone interested in writing or outlining long-term scenarios. We not only furnish suggestions for new scenarios, but also provide contexts, orientation and information. Four scenarios are developed at some length to illustrate how such scenarios might be created. We consider one of these to be the most reasonable and persuasive; the others represent limiting cases of pessimism and optimism (from the perspective of a space professional).

As part of this activity we formulate, name, and assess several other projections of the future of space development from different perspectives--but only in a very brief preliminary way. These also use the scenario technique, and are helpful in the creation of the detailed scenarios. Even their descriptive titles can be helpful to clarify and stimulate discussion.

Although we don't consider this project to be one of NASA's highest priority activities, we believe that it should have a high enough priority to receive some attention at almost all levels of NASA as a potential producer, receiver, writer, contributor, or advisor.

Since many people find that writing, reading, revising, or suggesting scenarios is stimulating and enjoyable, there is no need to make it an onerous or required activity. If an opportunity for voluntary participation is made available within NASA, we expect that enough people would participate at almost every level to permit this activity to be

performed adequately with a very modest amount of official support and/or encouragement. Those who feel uncomfortable with such scenarios or the conscious formulation and exploration of "images of the future" need not participate. The number of people who find it useful, enjoyable, or stimulating should be large enough to preclude the need for any special effort to induce further participation, other than providing a reasonably receptive atmosphere and a minimum level of organizational and logistical support.

To summarize and extend the discussion, we list below eight motivations or reasons for generating and disseminating long-term scenarios and appropriate images of the future.

1. FUN AND SCHOLARSHIP
2. SURPRISE-FREE PREDICTIONS WHICH ARE INTERESTING IN THEMSELVES AND SUPPLY UNDERSTANDING AND CONTEXT FOR IMMEDIATE ISSUES AND TRENDS
3. AMMUNITION FOR BUREAUCRATIC AND POLITICAL ACTION
4. AMMUNITION, INSPIRATION, AND ARGUMENTATION FOR A "LOBBY FOR THE FUTURE"
5. EARLY WARNING AND INCREASED SENSITIVITY TO CURRENT AND NEAR-TERM ISSUES AND EVENTS
6. REFLECTION AND REINFORCEMENT OF A BASIC PHILOSOPHY OF SPACE AND THE FUTURE
7. A POTENTIAL BASIS FOR A GENERAL FUTUROLOGY "IDEOLOGY"
8. POTENTIAL FOR INSPIRATION OR USEFUL GUIDE FOR LONG-RANGE PROGRAMS

B. Systematic Formulation of
Space Scenarios

In a previous report^{*} Hudson considered five basic scenarios labeled respectively: Conservative, Moderate, Moderate with Breakthrough, Advanced, and Sober Far-Out. The titles of these scenarios more or less conform to their content. Within their context all of the scenarios were meant to be relatively surprise-free. Therefore, we did not include in the five scenarios anything which would surprise us enormously if it "actually occurred." However, we also briefly described three other scenarios which appeared to us to be less plausible; we defined and mentioned them because they usefully bracket the five basic ones; two of these three less plausible or "surprising" scenarios are on the pessimistic side, one on the optimistic.

First, on the pessimistic side, is a Bleak Scenario in which very many great difficulties appear. Outer space is uncomfortable or hostile to humanity, technologically it proves unexpectedly difficult, and the payoffs for success are low. Unexpected difficulties occur in developing specific space technologies and economic growth and technological advancement on earth are much slower than was generally expected. Thus, the motivation for space exploration and the needed economic surplus and technological capabilities are all much less than hoped for. Furthermore, either current neo-Malthusian prophecies are fulfilled or, worse still, the adventurous or entrepreneurial spirit is much suppressed. As a result,

^{*}Herman Kahn and William M. Brown, et al., The Next 200 Years in Space (NASA Bicentennial Planning), HI-2352-RR (Croton-on-Hudson, N.Y.: Hudson Institute, October 23, 1975).

even if affluence were to be high enough and technology competent enough for much greater exploitation and colonization of outer space, people would avoid these options. Thus the world suppresses the opportunity to find out if there were any remarkable windfalls to be found in outer space (e.g., the equivalent of finding oil in an otherwise unpromising area, such as in Saudi Arabia). Although this is an overkill scenario, several like it could be written that would make the outlook for space development bleak indeed, at least during the next century.

The reader should be aware of an even more "aggravating" possibility which we call the Tragic Scenario. This scenario turns out worse than the Bleak Scenario, even if the results might be less inevitable. From mistakes which are made horrendous accidents or wars may occur; political/ideological/religious movements may arise which turn people adamantly against space projects; or soluble problems are left unsolved and internal politics or bigoted attitudes lead to excessive neglect or even a direct renunciation of the space program. Alternatively, a neo-Malthusian prophecy is fulfilled, not because it was inevitable but because it becomes a self-fulfilling prophecy which leads to a hostile regressing world. Eventually, of course, society is expected to rebound in such scenarios (though this is by no means inevitable) but not for a very long time.

At the other extreme, we visualize a Utopian Far-Out Scenario in which nearly every space project pays handsome dividends, where before long enormous public enthusiasm arises and relatively great risks with people's lives are accepted to speed up space development. Early successes raise morale and commitment resulting in funding well beyond the hopes of the

early enthusiasts. Many space equivalents of the Klondike or Saudi Arabian oil are discovered--either as an inevitable result of the high level of activity or by luck; in any case these "unexpected" bonuses provide a great spur to even more development and activity. Extraordinarily important spinoffs of space activities and space discoveries regularly occur. The hope for more such by-products is used to justify even larger investments. A keen, but relatively cooperative international rivalry arises and adds extra zest to the "race." Finally, it turns out that space is an attractive place in which to live. Humans moving to space, or born and raised there, feel relatively euphoric: they are healthier, live longer, and lead more productive and pleasurable lives than those who remain earth-bound.

Between these two extremes lie our five former surprise-free scenarios. These scenarios furnish some of the take-off points for the ones developed in later chapters of this report. Since they also provide some useful language and imagery for discussing space futures we summarize them below for this purpose.

1. Conservative Scenario: In this scenario space activities evolve in a constrained, business-as-usual fashion for several decades. Primary interest lies in short- and medium-run results based upon hard economic and technological calculations. These calculations justify only a relatively low level of exploitation, except for some very specialized activities. Even the use of the Shuttle turns out to be unexpectedly low by both the military and civilian agencies. Worldwide economic progress and

technological advances are disappointing, resulting in diminished technological capabilities and greater competition for governmental funds. Consequently, even funded space projects are often aborted or cut back. Technological progress in many areas occurs only in fits and starts because of erratic support. As a result, even the inadequate funds supplied are used inefficiently.

2. The Moderate Scenario also corresponds to a business-as-usual orientation. Indeed, 20th century public attitudes differ little from those of the Conservative Scenario. However, the Shuttle is successful, public interest in space grows gradually, and greater economic and technological progress occurs on earth. Business applications of space by INTEL-SAT, Satellite Business Systems,* and others are successful. Also, many of the projects discussed in NASA's Outlook for Space (OFS) study,** including some space industrialization, turn out to be reasonably successful. The result is a steady, sometimes rapid, increase in the use of cis-lunar space after the late 1980s. The Moderate Scenario might well be a second choice for the surprise-free outcome preferred by many within NASA. (The modification of this scenario, described next, may be the preferred relatively optimistic scenario in NASA today.)

3. Moderate Scenario with Breakthrough reflects expectations that are quite well grounded in current technological and political realities.

* See Bro Uttal, "I.B.M. Reaches for a Golden Future in the Heavens," Fortune, June 1977, pp. 172-184.

** National Aeronautics and Space Administration, Outlook for Space, SP-386, 3 vols. (Washington, D.C.: Scientific and Technical Information Office, January 1976).

Although a relatively sober projection, it has a single point of relative optimism: something happens in technology, space, or public opinion about the year 2000 (or earlier) which: 1) permits a rapid dramatic reduction of the cost and difficulty of transporting people and equipment into earth orbit; 2) greatly improves the perceived returns from space investment; or 3) makes greater public funding politically available. In any case, the prospects change favorably and dramatically. Much doubt and equivocation about major efforts in the exploitation and exploration of outer space disappears and a considerably more rapid development results.

4. Advanced Scenario: This is similar to the above Moderate Scenario with Breakthrough, except that increased interest, increased investment, and successes in space-oriented activities occur much earlier or much more intensely. Technological progress is substantially faster. This earlier and more active development of space could be brought about or supported by a backlash against prior anti-technology trends; it could even become a self-fulfilling prophecy--a self-reinforcing trend. It could also be strongly influenced by appropriate NASA and governmental information programs, such as a very persuasive analysis and widespread dissemination of the implication of its successes, or by some unexpectedly favorable events (e.g., early dramatic results in space industries). An unexpectedly successful public relations program by an expanded National Space Institute or another "Sputnik" type event could also play a central role.

5. Sober Far-Out Scenario: We assume here a wave of revived interest and relatively great early success. Resources allocated to outer

space and the return from these resources grow so rapidly that the results strongly affect events on earth. Before very long gross world product is favorably affected by the events in space. The new source of economic growth stops the declining growth rates experienced in the other scenarios--thereby leading to a remarkably wealthy world and a very different society, beginning early in the 21st century.

We consider all of these scenarios to be "surprise free" in a technical sense. It simply means that some relevant group, in this case the Hudson Institute, finds that within the assumed societal context no surprising events occur--although the potential range of plausible events can be large. Actually, it would be very surprising if some important surprises, both furthering and hindering the exploitation of space, did not occur in reality. In the Conservative and Moderate scenarios unexpected positive developments are assumed to be roughly balanced by unexpected negatives. Thus, these two cases are surprise-free, on balance, though both positive and negative surprises would almost certainly occur. This implies that our third scenario should offer at least one important surprise that, on balance, would be quite helpful.

Scenarios four and five would depend upon a general revival of interest by the public before they could be deemed surprise-free. This interest could arise accidentally, as the result of successful projects with substantial visible benefits, or might follow from a deliberate program by NASA and others that could demonstrate the wisdom of making such investments.

For convenience the titles of the eight basic scenarios are listed below:

- | | |
|-----------------|-------------------------------|
| 1. Tragic | 5. Moderate with Breakthrough |
| 2. Bleak | 6. Advanced |
| 3. Conservative | 7. Sober Far-Out |
| 4. Moderate | 8. Utopian Far-Out |

These scenarios have been formulated in largely technological terms and then ordered on the basis of technological and economic optimism. Although we wish to focus strongly upon technological and economic issues and possibilities, we also find it necessary, for other than the simplest treatment, to establish political, cultural, and social contexts (which may also have some value in images other than space futures).

Our eventual aim (in other projects, particularly in our Prospects for Mankind studies) is to elaborate upon some relatively detailed images involving political, cultural, and social issues and their interaction with technological and economic ones. Some of the technological and economic issues from the Prospects for Mankind studies are used as inputs to the scenarios in this report.

The Hudson Institute has completed a number of "futurological" studies. Some are intended to be serious predictions of the future--particularly if the scenarios have less than a 15-year time span. Those dealing with longer time spans are of course progressively more speculative. For basic economic and technological trends, however, reasonably accurate long-term projections appear to be possible--at least this has often been true in the past century or two. Some very basic social and cultural trends may also be successfully projected in a relatively routine fashion in both the medium and long run (see discussion of Long-Term Multifold Trend

in The Next 200 Years^{*}). However, many surprises do occur and most attempts to make long-run projections--and often even short-run projections--about detailed aspects of society generally lead to grave errors--and usually the more detailed the projection, the graver the errors.

This report portrays several long-range images of the future that are intended to be plausible--and acceptable as a context for our projection. Such images give perspective, orientation, or insight into real possibilities, without attempting to be a blueprint or a map to the future. We hope that many who are not familiar with this kind of an approach will be "awakened" in some unanticipated ways by this effort. One possibility is that the "detailed" context will play much the same role as a diagram in a mathematical proof--the diagram is not essential to the proof, but is very useful in giving a concrete example which both stimulates the imagination and clarifies the argumentation.

A context for viewing both current and future space programs should be useful not only to space professionals but also to others with a less than professional interest in space programs. If we have done a "good job," the report (unlike a diagram for a proof in mathematics) should also be entertaining. One of our objectives is to be playful, but, like much play, the activity has very serious goals. It should raise many issues and questions for which answers are needed, and should stimulate efforts toward finding them.

^{*} Herman Kahn, William Brown, and Leon Martel, The Next 200 Years (New York: William Morrow and Company, Inc., 1976).

C. Some Basic Political, Cultural
and Social Contexts

We have mentioned that our basic interests are technological and economic. But in pursuing technological and economic possibilities we find it essential to have a suggestive, if simplistic, concept of the likely political, cultural, and social milieu. The range of such milieus is so extraordinarily large that "futurologists" find it very hard to get a serious handle on them--despite all that has been written in this area. Our approach is first to set forth a series of very sparse political, cultural, and social contexts containing various ideas for scenario components. We then order these contexts in terms of decreasing attention and investment in space, though this order is not necessarily rigorous for the contexts as set forth--and further, over time some of the contexts could change and lead to a reordering of the list. These contexts are elaborated in varying amounts of detail, from a paragraph to a few pages. Because of their brevity, even the lengthiest discussion is necessarily without complexity or nuances. Of course no model of an advanced society which is pictured as simple, homogeneous, and/or ideologically unchanging over time can be very plausible--particularly if dramatic changes in its technology continue to occur. However, such simplicity has many advantages for our purposes. In particular, it enables us to speculate about the effects of a large variety of socio-political trends.

We have characterized fourteen political, cultural and social contexts as follows:

1. An Extreme Efflorescent Society--Intensive Darwinian Competition.
2. A Relatively Cooperative and Benevolent Efflorescent Society.
3. A Technological and Growth-Oriented Utopia--a Skinner-type Society.
4. A Technological and Growth-Oriented World, but "Normally Developing."
5. A Competitive, Nationalistic, and Somewhat Militant World.
6. A "Small is Beautiful" (when appropriate) Society.
7. Business-as-Usual Space Development Dominated by the U.S. and U.S.S.R.
8. A Triumph of Garden over Machine* in OECD Countries (or perhaps just a "New Class," "No Hassle" OECD).
9. A Triumph of Garden over Machine Worldwide (or a "New Class," "No Hassle," Society Worldwide).
10. A Low Growth "Economic Malaise" World.
11. A Rigid Emphasis on Stability, Localism, and Risk Aversion**-- in OECD Countries.
12. A Rigid Emphasis on Stability, Localism, and Risk Aversion-- Worldwide.
13. An Anti-Technological, Anti-Growth OECD.
14. An Anti-Technological, Anti-Growth World.

* Some well-known American literature extols the virgin forest and the rural, agrarian or wilderness areas of the U.S. that were formerly untouched and then became a refuge or earthly Garden of Eden for European man. However, the U.S. is now, also, the most technological nation in the world. During its history a continual struggle has occurred between the pastoral, rural or wilderness ideal and the rapid, almost ruthless, industrialization of the continent. Sometimes the two fought, sometimes they merged into a single whole, sometimes they settled for an uneasy truce. We visualize the Garden Society as a modernization of the rural, pastoral ideal; a possible future society whose ideology is directed toward maintaining a high quality of life, but which shows little change and dynamism. A good discussion of these issues can be found in Leo Marx' book The Machine In the Garden.

** See Appendix A for discussion of these terms.

The above list contains more cases than can be addressed seriously, and probably makes more distinctions than interest the average reader, but we have found such a list of possible contexts useful--particularly before we decide which ones to use or emphasize in the subsequent scenarios, as well as to make explicit some of the possibilities which we are not using.

In writing scenarios we tend to focus much more on the short-run projections in order to make them more realistic, and to address the political, cultural and social issues in greater detail. Nevertheless, we generally cannot get as good a grip as we would like on technological and economic issues. Within any of the contexts set forth above, the degree to which these issues can be resolved permits the development and exploitation of space to occur more or less favorably. Indeed, we treat particular issues with varying degrees of optimism or pessimism to better understand the range of feasible outcomes and to isolate and highlight specific issues. That is, within a fixed political, cultural and social context, a substantial degree of technological and economic variation is possible. We use the following 12-point optimism-pessimism scale for the societal inputs:

1. Total (perhaps almost religious or manic) commitment
2. Almost total enthusiasm
3. Reasonable and prudent enthusiasm
4. Normal optimism
5. Guarded or cautious optimism
6. More or less objective neutrality
7. Guarded or cautious pessimism
8. Relatively strong pessimism
9. Very negative expectations, combined with a reasonably open attitude towards results
10. Blind, but passive, total pessimism
11. Active, but not very intense, hostility
12. Active and intense hostility

The upper portion of the fourteen political, cultural, social contexts is likely to, but need not, reflect attitudes of reasonable to enthusiastic optimism with regard to space technology and space economics. The lower portion is likely to be associated with a reasonable to dedicated pessimism. Although very simple, this correlation fits our other objectives; thus more complex ones are possible (e.g., a blind dedication to research in biology, or undersea exploration--and a negative attitude to space as a diversion of interest or resources). However, it is possible to combine most of the contexts with almost any societal attitude on the optimism/pessimism scale. Generally, in our scenarios, the higher a context is on the socio-cultural list, the more optimistic are societal attitudes, and vice versa. In our new Moderate (but generally optimistic) Scenario (Chapter VI) we deliberately construct an important and influential institution which is at 1 or 2 on the optimism scale. (In our judgment most NASA personnel range from 3 to 6, the rest of the government generally from 6 to 9, as does most of the educated and lay public; very few groups would have a 10 to 12 rating.)

We now briefly discuss the 14 political, cultural, and social contexts.

D. The 14 Contexts

1. An Extreme Efflorescent Society--Intensive Darwinian Competition

We assume that mankind gradually comes to take seriously the biblical injunction "to be fruitful and multiply" and pursues this objective with an almost manic determination and, except for knowledge and wealth, with an almost complete disregard for conflicting values (safety, pleasure,

equality, etc.). Society increasingly sponsors intensive research in biology as well as in space technologies and develops the desire and ability to modify human beings as well as plants and animals in order to adapt them better to local conditions, both in space and on earth. It even becomes relatively ruthless about getting rid of, or terminating, "false starts"--species which have been initially successful but were then found to be less competitive or adaptable than later "designs." If there should be success in creating a high level of artificial intelligence, an important decision might ultimately be needed as to whether the injunction "to be fruitful and multiply" includes sufficiently intelligent computers and robots. Even the eventual replacement of man by machine cannot be ruled out (assuming that a sufficiently creative intelligence can eventually be designed into self-reproducing machines). Whether this occurs or not, many kinds of cyborgs and other kinds of man-machine combinations of extraordinary intimacy and competence are likely to arise.

In addition to research in biology, cybernetics, and automation this context assumes huge investments in space development and an extraordinary amount of activity as long as the drive "to be fruitful and multiply" continues.

2. A Relatively Cooperative and Benevolent Efflorescent Society

Once again mankind decides to be fruitful and multiply--to fill every acceptable niche and corner of the universe with life of one sort or another and particularly with preferred forms of human life. But the culture avoids ruthlessness and maintains great concern for other values (safety, art, happiness, etc.). The people are less willing to take big

risks, pay exorbitant prices, "discard" as many experiments, or to be callous with somewhat less competitive variants. Nor are they as willing to pursue genetic adaption as intensively as in the first context.

Some Darwinian selection and competition occurs but with much alleviation of this process and a strong emphasis on a cooperative and benevolent society which cares for and protects its progeny. However, there is still great emphasis on biological adaptation and on genetic design to facilitate such adaptation.

3. A Technological and Growth-Oriented Utopia--A Skinner-type Society

For simplicity it is assumed that basic behavioral science theories similar to those addressed by B.F. Skinner in such works as Walden Two and Beyond Freedom and Dignity are found to be feasible; in principle, can be applied worldwide; and are especially useful for societies living in outer space. Therefore, on earth and in space, societies soon develop in which almost all individuals are relatively well balanced, highly motivated, basically cooperative and "law abiding." At the same time high levels of initiative, courage, daring, and dynamism are maintained and even, but only where needed, a useful level of aggression and competitiveness. Many technological growth enthusiasts would opt for this society--at least as we describe it here. Of course, whether it could really work out in an attractive form is at best an open issue. That is, it may be completely impractical; or it may only be practical in a society like "1984" or "Brave New World," rather than in the kind of democratic, individualistic, pluralistic society which most people would prefer.

Our version of Skinner's Utopia not only accepts controlled ways of raising people, but assumes great advantages are inherent in genetic manipulation, chemistry, surgery, behavioral modification and so on. Also, an intense process for monitoring immigrants into the society would exist (but presumably for positive reasons unconnected with the concept of "big brother watching you"). Thus, in this scenario the kinds of people that are desired for various places and roles in space--and to a great extent on earth--are "created," but in a positive sense.

We add that the above society has more than a touch of the efflorescent world views, but does not take them as intensely or seriously as in contexts 1 and 2. In fact this context includes many of the attitudes of the "more humanistic societies" described below. In this context society does not seek population growth as an end in itself. It does seek rapid economic growth, but also a high standard of living and a high quality of life as it defines these. It also sets exceedingly great value on knowledge--especially science and technology. But growth of population is desirable only as necessary to fulfill these values rather than as an end in itself.

While this culture is not hostile to population growth it has great confidence and dynamism and a very reasonable faith that it can deal with any likely increase in population, certainly from the viewpoint of economics and technology, and also from many other points of view. They would consider somewhat foolish the "threat" that the world could be overwhelmed by excessive population growth.

4. A Technological and Growth-Oriented World, but "Normally Developing"

In this society we assume that the kind of intense domestic and foreign problems associated with nation states in the 18th, 19th and 20th centuries become solved, particularly the problem of wars and other destructive competition between large nation states. The nation-state retains a dominant role, but mainly because there is no obvious replacement and not because it retains a high level of loyalty and dynamism. There still exists some destructive competition, some destructive conflict, much neuroticism, some problems with crime, terrorism and outlawed behavior--as well as all the usual kinds of deviates--but all on relatively low and diminishing levels. Space development somewhat parallels the turbulent early growth of the United States (but without the Civil War) rather than within the kind of utopia described in Context 3. But it is more like the growth of the United States than the violent events which occurred during the rise and fall of the Spanish and Portuguese empires.

5. A Competitive, Nationalistic, and Somewhat Militant World

This context assumes that, politically, the world doesn't improve much over its current state; in fact, it deteriorates somewhat. This occurs in part because some new nations (e.g., China and Brazil) as well as several European nations become very powerful and enter the "space race"--that is, there is very little coordination between these various competitive national efforts. Rather there is a serious attempt by some nations--or groups of nations--to seize certain preferred regions of space

and exploit them for benefit of the homeland on earth. As a result problems arise among the various competing countries and groups and between colonizers and colonized--and also eventually between those "colonies" or populated regions of space that manage to throw off the "yoke" of the home country and the other actors in the system. It can be considered somewhat as a "replay" of the developments in the 16th through 20th centuries when the West expanded in an extraordinary fashion and colonized almost every other country in the world (except for Ethiopia, Iran, Thailand and perhaps China). There are, of course, huge differences since there are no native or indigenous peoples involved. Further, even the initial space colonies would have a high standard of living and certainly be much more technologically oriented than the homelands. Therefore, a better parallel might be that of the early Mediterranean world in which the Persians, Egyptians, Greeks, Phoenicians, Romans (and later Carthaginians) fought among themselves while colonizing the entire Mediterranean world (a large part of which is now the Middle East and Southeast Europe). In this parallel there were many cases in which the colonies became independent and powerful very early, as well as those in which the problems of an indigenous population were on the whole relatively easy to deal with.

6. A "Small is Beautiful" (when appropriate) Society

This is the first context in which we don't have aggressive attempts to exploit outer space--rather it is only promoted by those who are professionally interested and by adventurers tempted by the fact that "space is there." A negative attitude is usually displayed towards aggressive promotional attempts, but not a hostile one. Therefore, when obviously

good ideas arise or if an extremely persuasive case is made, space projects are pursued, but the burden of proof beyond reasonable doubt is on the advocates who are a small minority. The underlying concept of this context is that more often than not "less is more," at least until a satisfactory case can be made to the contrary. However, another version of this context could attain a high level of activity in space--for example, in order to remove many "polluting" activities from earth (e.g., nuclear power). It is conceivable that satellite solar power stations might soon become desirable in order to reduce environmental problems on earth. We believe this is unlikely to occur, primarily because terrestrial energy problems are unlikely to be sufficiently severe--but it is possible that they may be judged to be sufficiently severe by the people concerned. Because space could become a relatively open frontier with a high level of industrial activity, this context is placed above Context 7.

7. Business-as-Usual Space Development Dominated by the U.S. and U.S.S.R.

It is assumed in this context that within the next 30-40 years these two countries obtain a lead on the rest of the world that is so large and successful that it accelerates their economic and technological growth on earth. In addition, their early advantages in space tend to expand almost without a visible limit. This situation creates a problem of "the haves" and "the have nots" similar to that which dominated international politics in the late 19th and early 20th centuries. One could also imagine some political friction between the "big two" and the latecomers. To continue the historical parallel there could be some groups like the French who were a little late but still did moderately to reasonably well in the

competition for colonies; and then groups like the Germans and the Italians, and for a while the Japanese, who were too late to acquire many colonies, since almost all of the good ones had been preempted by others--and they resented it greatly.

Despite the competition among various powers the Americans and the Soviets tend to stake out, where possible, huge preferred regions in space for their own use. They do not use them very intensely initially, but enough to maintain their claims. Compared with Context 6 above, this could result in a less rapid development of outer space, but still not slow, as the competition between the great powers spurs on their desire to take over valuable "space property." One result is that exploratory activities in space tend to maintain a relatively high level.

8. A Triumph of Garden over Machine in OECD Countries (or perhaps just a "New Class," "No Hassle" OECD)

This context assumes that almost all the OECD countries (but none of the others) soon adopt an ideology which has been espoused by the New Class,* in particular, and a relatively high percentage of the upper-middle class in general. The thrust of this ideology, while not always anti-technology and anti-growth, includes the New Emphases (listed below). These are pursued with such intensity that it almost amounts to a "no 'growth' society." It contains many nuances which encourage groups who are anti-technology and anti-growth oriented. The ideology itself is not committed to the "no growth" concept and does not completely prevent

* See Appendix A for a description of the New Class.

space projects. Indeed space development could still proceed with reasonable intensity in an optimistic version of this context, but its growth rate is at least a factor of two slower than that in any of the above contexts. The New Emphases mentioned above for this society are:

1. RISK AVERSION
2. LOCALISM
3. COMFORT, SAFETY, LEISURE AND HEALTH
4. PROTECTION OF ENVIRONMENT AND ECOLOGY
5. LOSS OF NERVE, WILL, OPTIMISM, CONFIDENCE, AND MORALE
6. PUBLIC WELFARE AND SOCIAL JUSTICE (INCLUDING EQUALITY OF RESULT)
7. HAPPINESS AND HEDONISM
8. GENERAL ANTI-TECHNOLOGY, ANTI-ECONOMIC DEVELOPMENT, ANTI-MIDDLE-CLASS ATTITUDES (E.G., "SMALL IS BETTER" AND "LIMITS-TO-GROWTH" MOVEMENTS)
9. MANY MODERN FAMILY VALUES
10. GENERAL DE-EMPHASIS OF (OR EVEN HOSTILITY TO) THE THIRTEEN TRADITIONAL LEVERS
11. INCREASING SOCIAL CONTROL AND "OVERALL PLANNING" OF THE ECONOMY OF THE "WRONG" SORT
12. ADVERSARY REGULATORY ATTITUDES
13. INNER SPACE (OMPHALOSKEPSIS) AND/OR CONCERN WITH SELF GENERALLY, PERHAPS EVEN AN EMPHASIS ON MYSTIC OR TRANSCENDENTAL VALUES

-
9. A Triumph of Garden over Machine Worldwide (or a "New Class," "No Hassle," Society Worldwide)

This context is similar to the one above but instead of growing competition from the Soviets, from an emerging Brazilian giant, and others, the non-OECD world quickly adopts much the same ideology as the OECD nations. Thus a malaise in space development, or at least a lack of dynamism, continues for much longer. However, a competitive spirit eventually reappears and creates an increasingly dynamic attitude toward space development. The timing of this change to an eventual great competition--especially from the non-OECD world--would determine the nature of the optimistic or pessimistic variations.

10. A Low Growth "Economic Malaise" World

In the industrialized countries recently emerged upper-middle-class elites often feel that further economic growth increasingly interferes with their standard of living and their quality of life. Furthermore, a sub-group, which we have called the New Class, not only feels this with great intensity but has disproportionate influence because they tend to control both the popular and prestigious media, in addition to great influence in education, government and several religious groups.

The basic historical analogy to this context is with the Portuguese and Spanish empires which initially expanded with great speed and success but tapered off relatively soon and more or less stagnated from that point on. Our future version of that world would depict the current worldwide economic malaise continuing for some decades. This greatly depletes the resources that would otherwise be available in the early 21st century for space development. However, in an optimistic outcome of this case, the development of space itself, after 50 to 100 years, would help to pull the world out of its malaise.

11. A Rigid Emphasis on Stability, Localism, and Risk Aversion--
in OECD Countries

The press and popular magazines tend to suggest that the New Class will "triumph" soon. We believe that this is very unlikely within ten years, but could happen before the end of the century. If they do prevail, a modern version of past societies run by aristocratic, educated elites could occur--such as the Confucian era in China. An extreme rigid objection to change has characterized such societies, especially changes which interfere with established institutions or customs. For example, prior to

the 20th century in China, a country which had a thousand-year-old tradition of ancestor worship, it was very difficult to build a railroad or a highway without disturbing or destroying cemeteries. To do so it became necessary, literally, to call out the troops. In this context we imagine that the OECD countries have many figurative "cemeteries" which are not to be disturbed. We emphasize, however, that we are visualizing a general attitude that is basically hostile to innovation and implies an enormous reduction in technology applied to large new projects including, almost inevitably, most proposed new space developments.

12. A Rigid Emphasis on Stability, Localism, and Risk Aversion--
Worldwide

We assume that the rest of the world follows the OECD countries and visualize the social context in the above scenario becoming pervasive, worldwide. This is not plausible today, because of the "revolution of rising expectations" in the Third World countries. While many Third World intellectuals pay lip service to the New Class ideology, they are most unlikely to follow it in practice. In a mild version of this context an extreme amount of lip service is given which does affect Third World growth rates and technological advancement. In a stronger version much more than lip service is given--but this would be very unlikely to occur much before the turn of the century.

13. An Anti-Technological, Anti-Growth OECD

In this context the slowdown in anticipated space activities is quite dramatic. People no longer acquiesce passively when other groups push space efforts; rather they take a relatively active opposing role.

Some of the more extreme attitudes are applied to proposed space projects. People object to the potential destruction of lunar "landscape," the possible loss of lives and treasure in outer space, and potential effects on the upper atmosphere. They are especially hostile to new problems that might be created and the unknown risks that inevitably accompany any major innovations and therefore new activities in outer space.

The slowdown cannot be permanent since the Soviet Union or the newly emerging economic powers, such as Brazil, eventually take an active interest in space and their activities begin to swamp the efforts of the OECD world. This may in turn arouse counter-efforts or it may not, but in neither case does it lead to a long-term neglect of space development. However, activities in space supported mainly by the Soviets and by the new emerging powers would be substantially below that which would occur if the OECD world chooses to pursue these objectives.

Here again competition from the rest of the world eventually would make the basic OECD posture intolerable--but this change may come very late.

14. An Anti-Technological, Anti-Growth World

In this context it is not just the OECD countries which become enamored with the new attitudes, but the world as a whole. As the poorer countries become more wealthy they gravitate toward the culture models of the OECD world and settle for the new "traditional" lifestyle of these countries. The low economic growth of this "stagnant" world is a matter of apprehension only among a dwindling number of people with "reactionary" laissez-faire attitudes that are anathema to the dominant culture.

Chapter II

THE BASIC INTERNATIONAL CONTEXT

A. Watersheds of History

Except possibly for some religious events, the two great watersheds of human history have been the agricultural revolution, which started in the Middle East's Fertile Crescent some 10,000 years ago, and the industrial revolution, which began in Holland and England about 200 years ago. Of course, many are now arguing that the second half of the twentieth century has seen or is seeing another watershed. Some would emphasize the introduction of nuclear energy and explosives; some would emphasize the ability of man to leave the earth; some would emphasize the peaking of growth rates in world population and gross world product; some would emphasize the universalization of the industrial revolution; while finally some would emphasize almost the opposite--the emergence of physical or social "limits to growth."

In any case, in much the same way that the agricultural revolution earlier spread around the world, the industrial revolution is now also spreading and causing a permanent change in the quality of human life. However, instead of taking 10,000 years, this second diffusion process is likely to be largely completed within a total span of about 400 years, or roughly by the mid or late 22nd century. What we call the super-industrial and post-industrial economies are now emerging, to be followed eventually by corresponding changes in society and culture as a whole.*

*Various authors have developed and expanded notions of "post-industrial" economy, society, and culture. Preeminent among these in the depth and sophistication of their analysis are Daniel Bell, The Coming of

This last may be accompanied and followed by an era of space exploration and space exploitation which may introduce an equally startling change in human history. In fact, it is one of the purposes of this report to use the scenario technique to explore, dramatize, and illustrate some of the possible interactions of the development of a solar economy, society and culture together with likely events on earth--in particular how such developments in outer space might affect the "post-industrial culture" on earth and be affected by it.

In order to characterize the nature of some changes that will occur, it is useful to distinguish four kinds of activities: primary, secondary, tertiary, and quaternary.

Post-Industrial Society; A Venture in Social Forecasting (New York: Basic Books, 1973), and, with a very different manner and emphasis, Peter Drucker, The Age of Discontinuity (New York: Harper & Row, 1969).

We distinguish here among:

Economy:	economic and technological activity
Institutions:	laws and organizations
Culture:	style, values, national character and attitudes
Society:	the whole

Super-Industrial Economy refers to large size and scale of modern enterprise and the importance of its impact on the external social and physical environment.

Post-Industrial Economy refers to a future very affluent economy which meets its industrial and material needs with a small percent of its work force and economic effort. The term is deliberately chosen to be neutral; it does not describe the corresponding society.

Presumably the economy emerges first; then the institutions and the culture change; finally (hopefully), a harmonious society evolves.

Post-Industrial is often at the same time Super-Industrial. Thus, the United States is a post-agricultural society (since less than five percent of its inhabitants are engaged seriously in agriculture) but it is also a super-agricultural society in terms of the variety of its products and the scale of its activities.

Primary activities are extractive, principally agriculture, mining, forestry, and fishing. One can think of a corresponding pre-industrial society and its culture as one mostly organized to "play games with and against nature."^{*} In earlier days for everyone in the city there were generally twenty in rural areas who supported the city dwellers by following some primary activity.

Secondary activities have mainly to do with construction and manufacturing. The corresponding society and its culture is mostly organized to "play games with and against materials." It is primarily an urban culture and has been characterized in our time by a nation-state political system with all of its well-known characteristics.

Initially the emerging post-industrial economy will be characterized by a service economy, emphasizing what we call tertiary activities. These are services which help primary and secondary activities. Conventionally they include transportation, insurance, finance, management, many governmental activities, much education and training. This results in a society and culture whose major activity is "games with and against organizations." Such a society is characterized by organizational and professional pluralism in the distribution of power and prestige. It is probably more suburban than urban, and may have more transnational than national corporate activities.

*The term "playing games with or against nature" and other uses of game metaphors refer to the extensive literature of gaming, simulation and role playing and should be thought of partly in a literal sense and partly metaphorically. The idea simply is that the major roles and activities of the individual in a primary society are preoccupied with activities which can be characterized as "playing games with and against nature" rather than as in the other cases "with and against materials," "with and against organizations" or "with and against communities." The basic inspiration for this terminology comes from Daniel Bell.

Early in the 21st century, we should expect a partial transition (i.e., in the rich OECD countries at least) to a different kind of service economy that can be called a "quaternary" or truly post-industrial economy. Here the primary, secondary, and tertiary activities will constitute only a small part of human endeavors; more and more people will do things for their own sake, and ends will become more important than means. Such a society can be characterized as playing games with and against people, with and against communities; and perhaps with and against oneself. It is in many ways reminiscent of pre-industrial culture. These quaternary activities could include many "mundane" activities such as:

Reading, writing, painting, acting, composing, musicianship, arts and crafts--particularly if done for their own sake.

Tourism, games, contests, rituals, exhibitions, and performances.

Gourmet cooking and eating, an aristocratic and formal style of life, epicurean and family values (including visiting, entertaining and "togetherness").

Hunting, fishing, hiking, camping, boating.

Acquisition of non-vocational skills.

Improving property (If caused by some non-economic motives), such as by gardening, upkeep, interior decorating, and the use of home-made artifacts.

Conversation, discussion, debating, and politicking.

Many other cultural and social activities.

Most welfare and social security.

Other "recreation," including the search for change, broadening experiences, adventure, excitement, and amusement.

But also such significant activities as:

Many public works and public projects done more for interest than for economic or research reasons (e.g., some space activities, some underseas exploration, much protection of the environment, monumental architecture).

Ritualistic and aesthetic activities (perhaps creating special structures and environments) including the evoking of images or feelings of splendor, pride, pomp, awe, and communal, ethnic, religious, or national unity or identity; oneness with nature and the universe, and various "explorations in inner space."

The creation of taboos, totems, demanding religions, traditions, and customs; arbitrary pressures, constraints and demands; moral and social equivalents of war; some other pressures and risks, including those involved with some of the more bizarre forms of "discretionary behavior."

Finally, the concept includes non-tertiary services to these and other quaternary activities.

If a transition occurs to a society principally engaged in these activities--a transition which could largely be completed some two hundred years hence--it would probably mark the third great watershed of human history. Future society would look back at what happened in these centuries of industrialization as mankind's most effective and pervasive transformation--a journey from a world basically inhospitable to its few dwellers to one fully commanded and enjoyed by its expanded multitudes.

B. The Difference Space May Make

Nevertheless, we suspect that many of our readers will be a little unhappy with the above story. It ends too soon. Does mankind really wish to "stagnate" in a kind of total quaternary society? Does it really wish to give up permanently its games with and against nature, games with and against materials, games with and against organizations? Our guess is that future man will reply, "not completely," though very likely, at least for a time, many will largely enjoy this post-industrial culture. In other words, we expect that most people will be quite happy living in and supporting this quaternary culture, but there will be many who will not enjoy it and others who cannot afford it--or at least want more economic progress or technological advancement than is implied in an early transformation

to a quaternary culture. These people will find that this kind of culture is lacking in excitement, challenges, and opportunities. Indeed life will be, to many, a bit boring. Many ambitious people will undoubtedly want to contribute to larger goals than establishing and reinforcing the even tenor of even a rich, comfortable and, in its own terms, interesting life. We suspect that space will become a major focus for many of these people. The existence of such a frontier, of such an area of activity, of such a locus of dynamism, initiative, and entrepreneurship should be very healthy for both the quaternary society that is developing on earth and for those who may wish to "progress" faster--either as a society, a family, an individual or as an industry or professional group. We expect that space activities will, first psychologically and culturally, and then materially, play a central role in making earth a better, more interesting place in which to live.

At least three possible space perspectives seem important to us: (1) Space doesn't make crucial or dramatic differences within the next 100 years; (2) it has an essential role in changing the world from a neo-Malthusian to a hopeful--perhaps even post-industrial--orientation; (3) it complements and enlarges post-industrial development but is not essential to it. However, it does improve the context for the development of a superior post-industrial society on earth and may create quite a different society in space. Thus, post-industrial society does not end man's future but begins a base from which to move into the solar system and then, possibly, into interstellar space. Whether or not the latter occurs, the openness, the opportunities, and the challenge of outer space can be a sustained profound influence on an otherwise excessively static or introspective earth society.

Although this study will emphasize the possibility that actual income and resources from space will be important to the earth, that space will generate many economically and technologically profitable activities, and that exploitation of space can have a major positive influence on the world's economic and technological future, we do not find such outcomes inconsistent with the view that the third perspective is appropriate and useful. Furthermore, the first two perspectives may have basic flaws.

We believe that NASA should tie its "official" central image of the future of space to the third perspective. Of course, the current neo-Malthusian popularity is so strong that a claim by NASA that space development could make the kind of difference suggested in the second perspective could be politically helpful to those who oppose a limits-to-growth image. Also, if the neo-Malthusian position was otherwise correct, and space could make the crucial difference suggested in the second perspective, a powerful argument would exist for supporting rapid, intensive space development. In any event it appears to us to be both morally and scientifically wrong, and also counterproductive, for NASA to support the neo-Malthusian perspective, even indirectly. For encouraging widespread support of space activities and for developing a solid commitment and high morale among those engaged in NASA activities, we would assert that the third perspective is quite sufficient. Perhaps paradoxically, it may also help to exploit the first two perspectives, neither of which is incompatible with the third. Moreover, NASA would not be advancing an argument which may be easily countered or weakened. In order to clarify this last point, we now sketch out some of the important elements of what we call our surprise-free Moderate Scenario that are not dependent upon space developments.

C. The Basic Surprise-Free Earth-Centered Scenario

We believe that any projection of the future should begin with a reasonable--or not unreasonable--surprise-free scenario which unfolds over time at least some of the simplest "data" that can measure or set limits to economic, demographic, and technological trends. It is impossible, of course, to get much agreement among futurologists that any particular set of data is preferred, because such a strong divergence of views exists--a divergence which, in part, reflects a genuine uncertainty. But it is usually possible to get a fair amount of agreement that one's choice is not stupid, ridiculous, wildly optimistic or pessimistic, etc.

However, even such agreement might be irrelevant. For example, the average economic growth rate per capita for today's most developed countries has, over the last 200 years, been roughly 2.0 percent. Overall this increase is about a factor of 50, from about \$150 per capita to about \$7,500 per capita. Yet if, in 1776, a serious 200-year projection had been made using the 2 percent figure almost all intelligent and knowledgeable people probably would have laughed. After all, the world had scarcely changed at all in average income since the beginning of recorded history. If such projections were based upon a 1 percent or a 3 percent growth rate (neither of which now, in retrospect, appears any less plausible than 2 percent) the outcome over the two centuries changes radically--by about a factor of 7--that is, to \$1,000 per capita or \$50,000 per capita, respectively.

With a proper recognition of the astonishing effect of small changes in average growth rates upon the long-term outcome, and therefore of the low probability of making good estimates over extended periods, we must still begin somewhere. We choose what we consider to be a surprise-free

projection adapted (and slightly modified) from our book, The Next 200 Years.^{*} The population and economic projections are shown below in Table 1. They were arrived at after as much deliberation as can reasonably be given to such considerations and are, of course, arbitrary to some degree. They were chosen as much for convenience and general acceptability as for a serious prediction and estimated in terms of a smooth curve (i.e., no attempt to include the effect of business cycles). Thus, the actual GWP in 1975 was probably about \$6.3 trillion. We call this a 10/20/200 world because it asymptotically approaches the values: 10 billion population, \$20,000 GWP per capita and \$200 trillion GWP.^{**}

The population projections will be found reasonably consistent with those made by the United Nations. They assume that the world population stabilizes after about a century. (If it doesn't, some serious problems may arise; but the most recent trends clearly suggest that it will.) More controversial, however, is the assumed growth in GWP which increases the average per capita income about a factor of 10. That is, our surprise-free world becomes rich, even by today's U.S. standards. The factor of 10 represents an average growth rate over 200 years of only 1.5 percent in per capita income--a rate which would be a disappointment currently for any growth-oriented nation. Indeed, our estimates use an average per

^{*}The modifications are partly due to recent data and events which have altered our views a little and partly to make the projections more acceptable. The principal change is the projection of a 10-billion world population, rather than 15-billion. The GNP/capita over time is roughly the same.

^{**}Although few people are likely to object to a population limit many (including the authors) would think that a limit to GWP is not reasonable even in an earth-centered context. Our assumption of a GWP limit mostly reflects a mathematical convenience; at the end of the 200-year period the world economies are still growing, but slowly, at about .25 percent annually.

Table 1

SURPRISE-FREE PROJECTION OF WORLD POPULATION AND GWP*
FOR THE BASIC 10/20/200 SCENARIO

<u>YEAR</u>	<u>POPULATION (BILLIONS)</u>	<u>GWP (AVERAGE) (\$ TRILLION)</u>	<u>GWP/CAPITA (AVERAGE) (\$ THOUSANDS)</u>
1975	4.0 (2.0)	6.6 (5.1)**	1.75 (2.8)
2000	6.0 (1.3)	20 (3.6)	3.3 (2.3)
2025	7.7 (.7)	43 (2.6)	5.6 (1.9)
2050	8.8 (.4)	74 (1.8)	8.5 (1.4)
2075	9.4 (.2)	106 (1.2)	11.0 (.97)
2100	9.7 (.1)	135 (.75)	14.0 (.66)
2125	9.9 (.04)	156 (.47)	16.0 (.43)
2150	9.9 (.02)	172 (.29)	17.0 (.27)
2175	10.0 (.01)	182 (.18)	18.0 (.17)

* GROSS WORLD PRODUCT AND GWP/CAPITA IN 1975 DOLLARS. THE FIGURES IN PARENTHESES GIVE PERCENT CHANGE PER ANNUM.

** THE 1975 GWP IS USUALLY ESTIMATED AT \$6.3 BILLION AND THE GROWTH RATE WAS MUCH SMALLER THAN 5.1 FOR THAT YEAR. WHAT APPEARS ABOVE IS THE CALCULATED RESULT OF A SMOOTHED OUT PROJECTION WHICH CORRECTS FOR THE RECENT RECESSION.

capita growth rate of more than 2 percent (and less than 3 percent) for less than the next 50 years. For the second 100 years it is substantially less than 1 percent. In this light the end result can hardly be termed optimistic--yet it has often been so labeled.

Probably the principal reason for the "optimistic" label is a widespread belief that came into vogue in the late sixties and was greatly intensified after the appearance in 1972 of the book The Limits to Growth^{*} which coincidentally was followed by a food shortage (1972), the energy and raw materials crises (1974), and worldwide two-digit inflation. All this supported the belief that the world was simply too small to sustain nations with growing populations and growing economies much beyond their present size. It is not surprising that adherents of that view would be taken aback by a claim that the population could more than double while the per capita income increases 10-fold without unduly straining the capacity of this "small" world. Yet this is a very moderate projection.

In order to make our surprise-free, moderate-growth projections palatable it was necessary to attempt to demonstrate that the principal prevailing concerns could indeed be resolved. This was done by spelling out plausible solutions to each of the major physical problems related to this burgeoning world, those concerned with population stability, energy, minerals, food, and environmental purity. The essence of our arguments are presented below to help convince the readers of this report that the position is at least plausible. Those who already accept this position may wish to skip the rest of this chapter.

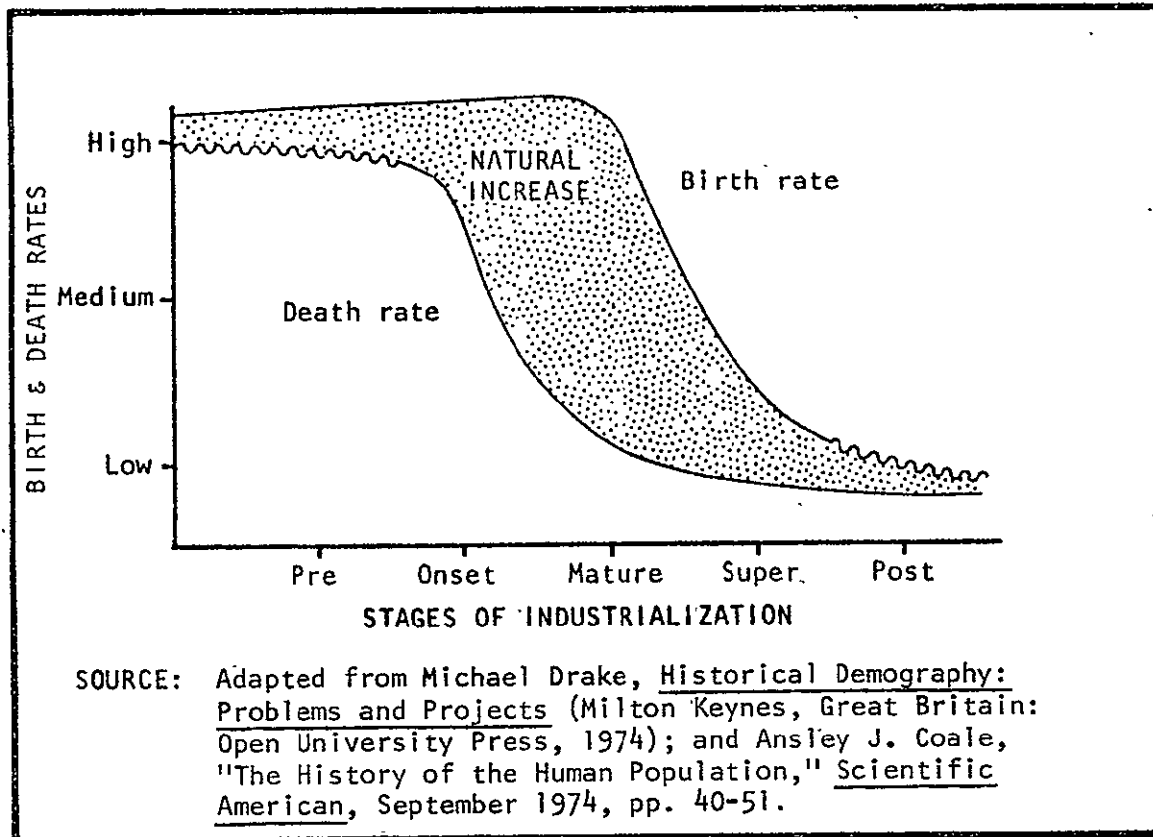
^{*}Donella H. Meadows et al., The Limits to Growth (New York: Universe Books, 1972).

1. Population

Our view of the approaching stability of the world's population is based, first, upon data showing that in recent years the birth rates for most nations for which we have statistics have shown a substantial decline. Indeed, such data, among other considerations, has led most demographers including those of the U.N. to project continually declining future birth rates for the world. Secondly, there is the widespread and growing formal interest of citizens, institutions, and governments in the control of population growth. This kind of interest leads to many kinds of actions that tend to reduce population (some of which might even be considered outrageous--the recent reports of the forced sterilization program in India, for example). Third, are the rapidly developing technologies for aiding in birth control. These technologies have been more effective in the more developed nations but over time undoubtedly will diffuse more deeply into the others. Finally, and possibly most important is the historical trend which is generally termed the "Demographic Transition." This trend which is unrelated to any of the other factors mentioned above has been observed for many decades in the industrialized countries. Although there may be occasional exceptions or short-term anomalous fluctuations in the predicted trend, the Demographic Transition is a general theory of population growth which is based upon the data available for societies which evolved from a pre-industrial to a fully industrialized or post-industrial status. The generalized result is presented in a schematic form in Figure 1. It indicates how such societies tended to move from a slowly growing population, in which both birth rates and death rates are high; through a rapidly growing phase as death rates dropped relatively

Figure 1

THE DEMOGRAPHIC TRANSITION



sharply over time after the modern society began to develop, with an increasing capacity to sustain the health and safety of its population; finally reaching once more a slowly growing, or perhaps stable, state in which the birth and death rates are both low and may be approximately equal. This experience has been common to the U.S., U.S.S.R., Germany, and Japan to name but a few examples. Many demographers believe it to represent the general pattern for the future. Although this result cannot be known to be true for the future it certainly should be plausible to use it as a basis for projecting future population.

2. Energy

To justify a surprise-free projection in which the Gross World Product increases almost 30-fold it is clear that much more energy will be needed than is consumed currently. How much more? To answer this question our first assumption is that the conventional wisdom is partly correct, the world has moved into a new era in which energy no longer will be cheap. This assumption might be wrong; if so, it implies that the solution will be less difficult than is expected. But if energy prices stay as high or perhaps become somewhat higher than current ones, in real terms, then we need to know where the energy will come from in such large amounts and whether we could afford it at the higher prices.

In response to these concerns we first examine the expected future demand for energy. With the assumption of continued high prices it is natural to ask what effect conservation practices and engineering redesign might have upon demand. Enough information is already available to suggest that with sufficient incentive and enough time rather astonishing

changes can be anticipated which will utilize energy much more efficiently than currently. Most energy consumed today is utilized at less than 1/10 of its physical potential. Therefore, given the incentives for efficiency, our growing technological capability, and up to 200 years to solve the efficiency problems, we assume that we would eventually utilize energy at least four times more efficiently than we do today. More particularly we assume twice today's efficiency in 50 years, three times as much in 100 years (see Table 2). With these efficiency parameters a calculation of future demand can be projected. In Table 2 this demand is taken to be in proportion to GWP/EFF.

We then need to look at the potential future sources of energy: the principal hydrocarbons (oil, gas, coal, oil shale, tar sands), the nuclear sources (fission--with and without breeders--and fusion), the geothermal alternatives (steam and hydrothermal reservoirs, hot dry rock, geopressured aquifers, magma outcrops, etc.) and the many forms of solar energy (collectors for buildings, solar thermal electric, photovoltaic, ocean thermal systems, wind energy, and the use of plants and organic wastes). Other sources of energy exist (tides, ocean currents, waves, etc.) which we ignore because they are quite limited and we find that we have a superfluity. The potential of the above principal energy sources is found to be so large that there are several, each of which, independently, can provide the total projected energy requirements of the world for far more than 200 years. This is well known, of course, for the "inexhaustible" resources: geothermal, solar, and fusion energy. It is less well known for fission energy and for hydrocarbons because of the tendency to confine our attention to proven reserves under present technology and economics

Table 2
ESTIMATES OF WORLD ENERGY CONSUMPTION
(Q = 10^{18} BTU)

YEAR	POP. ^a (BIL.)	GWP ^a (\$ TRIL.)	GWP/ CAP ^a	EFF. ^b	ANNUAL CONSUMPTION	CUMULATIVE CONSUMPTION (FROM 1975)
1975	4.0	7	1,750	1.00	.25 Q	--
1985	5.0	11	2,300	1.15	.35	3 Q
2000	6.0	20	3,300	1.4	.50	10
2025	7.7	43	5,600	2.0	.80	25
2075	9.4	106	11,000	3.0	1.25	80
2125	9.9	156	16,000	3.5	1.6	150
2175	10.0	182	18,000	4.0	1.65	230

^aHUDSON INSTITUTE STUDIES.

^bRELATIVE OVERALL EFFICIENCY ASSUMED FOR PRODUCTION, CONVERSION AND UTILIZATION OF ENERGY COMPARED WITH 1975.

rather than potential resources with likely future technology and economics. With the latter perspective we could, in principle, extract uranium from low-grade sources, including sea water, and combined with breeder or near-breeder reactors the potential would increase much more than 1000-fold over current estimates based on present reactors and known reserves which might last only a few decades. Or by including the solid hydrocarbon fuels with the conventional oil and gas the potential long-term resource becomes very large compared to current oil and gas reserves (see Table 3). Even here we have not included all the fossil fuels, only the principal ones. If fossil fuels obtainable from the eastern shales of the U.S. and the lower-grade oil shales were added they would increase the total potential shown in Table 3 several-fold.

Moreover, it should be stressed that even if all of these alternative resources were to be two or three times more expensive than energy is currently--an extremely unlikely conjecture--then as the efficiency of energy utilization also increased by a factor of 2 or 3 over that of present practices, the cost of energy per unit of "work" accomplished would not increase at all. It appears to us to be likely that the effective cost of energy (the average cost to accomplish most required tasks) will diminish substantially over the long term.

In contemplating either the potential new sources of energy or its more efficient utilization, we are not conjuring up hopeful unknown technologies which will appear in the distant future as breakthroughs which will solve our problems. Although this could and probably will happen it is not required for the argument. Rather our calculations rest on a set of technologies which currently exist or which are promising enough today

Table 3
RESOURCES OF PRINCIPAL FOSSIL FUELS
(Q = 10¹⁸ BTU)

	PROVEN RESERVES		POTENTIAL RESOURCES	
	U.S.	WORLD	U.S.	WORLD
OIL ^a	.3	3.7	2.9	14.4
NATURAL GAS ^a	.3	1.0	2.5	15.8
COAL (INCL. LIGNITE) ^b	15	95	30	170
SHALE OIL ^b	12	19	150	2000
TAR SANDS ^c	--	1.8	.2	10
TOTAL	27.6 Q	120 Q	185 Q	2200 Q
YEARS OF WORLD CONSUMPTION AT CURRENT PROJECTIONS	53	114	170	1000

^a EXPLORING ENERGY CHOICES: A PRELIMINARY REPORT (WASHINGTON, D.C.: FORD FOUNDATION ENERGY POLICY PROJECT, 1974).

^b DONALD A. BROBST AND WALDEN P. PRATT, EDS., U.S. MINERAL RESOURCES, U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 820 (WASHINGTON, D.C.: U.S. GOVERNMENT PRINTING OFFICE, 1973).

^c U.S., CONGRESS, HOUSE, "OIL SHALE--AN ACE IN THE HOLE FOR NATIONAL SECURITY," BY P. A. PETZRICK, IN SYNTHETIC FUEL LOAN GUARANTEES, HEARINGS BEFORE THE COMMITTEE ON SCIENCE AND TECHNOLOGY ON H.R. 12112, 94TH CONG., 2ND SESS., 1976 [NO. 56], APPENDICES 2: 586-587.

to be in active research and development. Of the many under development no single one is crucial to the argument. However, it is extremely implausible to expect them all to fail to produce energy in the future, even at 2 to 3 times current costs.

3. Minerals: Non-Energy

Although the debate on the future availability of raw material resources at tolerable prices includes renewable resources such as timber and water, the critical focus usually falls upon non-renewable minerals--especially the industrial metals. Our discussion is limited to this category.

First, it is advisable to question the label, non-renewable, when applied to industrial metals. Unless recycling were to be forbidden, these metals (except uranium and thorium for fission reactors) are not only renewable but in most cases the industrial process converts them from low-grade ores below ground into high-grade ores above ground. Of course, there will be some losses in the form of highly dispersed solid wastes or liquid effluents with low metal concentrations that end up in the ocean. But these can be kept quite small if the economic incentives to recycle them are adequate--or if the principal waste deposits are viewed as future mining sources when the technology and economics have become appropriate. Even now we can expect the amount of these wastes to be consistent with the economics of additional supplies--after environmental factors have been properly included in the economics. But these are minor considerations. The valuable scrap and other wastes are already being recovered in various recycling arrangements which appear almost

certain to become steadily more efficient. The principal reason for expecting a growing demand for minerals is not for replacing waste, but rather because of the world's expanding population and income. Will there be sufficient resources of the industrial metals to meet demand?

To respond to this question we examine present demand for two important categories of these metals. The first is that of the five clearly inexhaustible ones--inexhaustible because they constitute such a large fraction of the earth's crust that there is no conceivable way to use up the enormous quantities that are available. (None of these five are so uniformly distributed that they would ever need to be extracted from ores of average grade.) The second category which is termed probably inexhaustible lists the next seven metals, in the order of their current demand in the U.S. These two lists and the data on relative demand are given in Table 4.

First, we observe from the table that the five clearly inexhaustible metals constitute over 95 percent of the total demand. Second, if our judgment that the second group is probably inexhaustible is plausible then over 99.9 percent of the current and probable future demand for industrial metals can be reasonably satisfied. Thus, the overall problem, if any, would be reduced to that of the .1 percent of remaining demand (by weight) which includes all other metals. The crux of the problem then appears to depend upon whether a sufficiently convincing case can be made that the seven metals termed, probably inexhaustible, are plausibly categorized. We will run through the justification quickly. For more detail the reader is referred to Chapter 4 of The Next 200 Years and

Table 4

RELATIVE CONSUMPTION OF IMPORTANT
INDUSTRIAL METALS (1968)

<u>CLEARLY INEXHAUSTIBLE</u>	<u>U.S.</u>	<u>WORLD</u>
IRON	85.70%	89.83%
ALUMINUM	8.22	4.47
SILICON	1.05	.71
MAGNESIUM	.21	.09
TITANIUM	.02	.01
SUBTOTAL	95.20%	95.11%
<u>PROBABLY INEXHAUSTIBLE</u>		
COPPER	1.38	1.35
ZINC	1.23	.97
MANGANESE	1.19	1.76
CHROMIUM	.50	.45
LEAD	.25	.20
NICKEL	.15	.09
TIN	.03	.03
SUBTOTAL	4.73%	4.85%
TOTAL	99.93%	99.96%

SOURCE: H. E. GOELLER AND ALVIN M. WEINBERG, "THE AGE OF SUBSTITUTABILITY," SCIENCE, FEBRUARY 20, 1976, P. 683.

our primary basic reference, the prestigious U.S. Geological Survey publication, U.S. Mineral Resources.*

Copper which has the greatest demand of the 7 in the second category is also the one which appears to be most vulnerable to "exhaustion." Still if we consider the estimated potential resources from conventional mining we find that they come to about 1 billion tons of copper. To this we might add at least 3 billion tons which appear to be available from ocean nodules, the mining of which is expected to start within a decade. This 4 billion ton total comes to an average of 800 pounds per person in the projected stabilized world population. This is half again the amount of copper per capita that the U.S. has produced throughout its history. By this measure it might be adequate. Still we have a considerable cushion in the following: 6 billion tons are dissolved in sea water which might become a producing source in the future and 60,000 billion tons is in the top 5,000 feet of the earth's crust--most of it dispersed in rock formations but a substantial portion is in much higher than average concentrations, at least 10 times the average, that can be produced at somewhat higher than present costs (perhaps \$4/lb with current technology) if needed. Perhaps more important, however, is the consideration that almost all of the present uses of copper have available substitutes, generally aluminum. With minor exceptions copper is a metal of convenience or decoration. Its principal uses are as a conductor of heat and electricity. Aluminum is now a direct competitor for both purposes. Recently

* Donald A. Brobst and Walden P. Pratt, eds., United States Mineral Resources, U.S. Geological Survey Professional Paper 820 (Washington, D.C.: U.S. Government Printing Office, 1973).

thin glass fibers have also come to threaten to replace copper in telephone cables--and almost certainly will be successful. If inexhaustible aluminum and glass can replace it functionally, only sufficiently competitive prices will enable copper to remain an important metal in the long run.

For zinc the estimated potential resources are about 1,000 times the present annual consumption. Its three principal uses are for die-casting alloys, galvanized sheeting and for brass products. These three constitute about 73 percent of the demand for zinc. There are ready substitutes for the first two uses which constitute 50 percent of present demand; magnesium, aluminum or plastics for die-casting, and aluminum sheeting for galvanized steel now compete in price. Brass for the most part is an optional alloy and often is decorative rather than functional. Thus, of the current uses of zinc considerably less than the remaining 27 percent would be essentially dependent on zinc. Given the huge resource base, and assuming more efficient recycling will become desirable, it is difficult to become concerned about the exhaustion of zinc.

Manganese and chromium are quite plentiful, although the higher grades, as in most ores, are not necessarily distributed as users would prefer. For lead the potential resources not only appear to be nearly 1,000 times the current annual consumption but all of the present principal uses of lead (batteries, gasoline additives, ammunition) may well disappear, indeed, one of them (tetraethyl lead) is being phased out now. Moreover, in its main use, as a battery material, it is very efficiently recycled at present.

Nickel has very large resources, only the highest grade ores are competitive at present and these are threatened by the potential of the ocean nodules. For tin the world's resources are estimated at about 150 years of present consumption, at least half of which at present is in tinfoil for cans. Many of the uses for tin, including tinfoil, can be met by steel, aluminum or plastics. With such substitutes and improving recycling the more essential uses for tin should be easily met by the current known resource base.

Space buffs will quickly observe that in our discussion of mineral sources we have used only earth resources. As will be indicated later the moon and the asteroids are potential huge mineral resources and eventually are expected to furnish a large part of the requirements for space processing, very possibly during the 21st century. Indeed, very many technological advances or breakthroughs can be expected during the next 200 years which will tend to alleviate some of the more naive concerns about exhaustion of mineral supplies. However, it is important not to depend on unforeseeable advances if we are to make our case convincing.

4. Food

Our approach to the matter of adequate food supplies is to argue that present agricultural knowledge would permit food production with conventional farming to increase at least 20-fold over present world production. This is an argument that it can be done, not that it will be. What will happen is strongly dependent on social and political trends as well as on economics and technology.

The potential for increasing food supplies through conventional agriculture is shown in Table 5. The estimated increase is based on increasing (1) the amount of farmland, (2) the number of crops per year, and (3) the yield per crop--by employing current technologies for fertilizing, irrigating, obtaining high-yield seeds, and protecting crops and soil through pesticides, proper cultivation, and modern storage.

Today there are also a number of unconventional techniques for food production which are very promising. They include low-cost greenhouses, hydroponics, soilless agriculture, scientifically controlled growth chambers, agri-industrial complexes, genetic innovations, and artificial foods--such as single-cell proteins made in factories. All of these are in limited commercial production today and each has a potential for vast expansion which can only make the food supply problem less difficult.

Table 5 suggests that conventional agriculture can supply at least 20 times as much food as is produced today and if needed more than 100 times as much. How much food will be needed? If our projected stable world population is to have consumption standards equal to those in the U.S. today then a 10-fold increase in production would be required. Thus, it appears to be well within the world's agricultural potential.

5. Environment: Near Term

To assure acceptable standards of environmental purity and aesthetic landscapes in the near term it appears necessary to make two kinds of technological improvements. The first is to design all new installations to meet the standards set by society. This appears to be within today's engineering capability although in some cases an adequate design may

Table 5

POTENTIAL FOR INCREASED FOOD PRODUCTION

	<u>CONSERVATIVE</u>	<u>OPTIMISTIC</u>
1. INCREASED AGRICULTURAL LAND HARVESTED	FACTOR OF 2.5	4
2. MULTICROPPING	FACTOR OF 1.5	2
3. AVERAGE YIELD PER CROP:		
IMPROVED USE OF		
FERTILIZER	FACTOR OF 1.5	2
IRRIGATION	FACTOR OF 1.5	2
HIGH-YIELD VARIETIES	FACTOR OF 2	2.5
OTHER INPUTS	FACTOR OF 1.2	1.4
	<hr/>	<hr/>
MULTIPLICATIVE TOTALS	FACTOR OF 20	110

require research, development and testing that may take from 10 to 20 years. The phenomenal response of the developed world to the rather sudden pressures for improved environmental standards has thrust these problems upon the existing institutions rather rapidly and not all of them find it feasible to react as quickly as society would like. However, in principle, the new factories, mines, farms, dams, etc., only have to be designed to meet the new standards and usually that is expected to be feasible although sometimes the costs and regulatory difficulties can cause some serious protests and delays.

The more difficult problem is that of retrofitting existing installations and changing traditional practices in order to comply with the desired new standards. This poses a much more costly problem and in many cases will delay full compliance for a lengthy period. Such problems stand out in municipal systems for waste disposal and sewage processing, and in rural farming systems which create a vast amount of water pollution through uncontrolled runoff. In many, if not most instances, both the municipal systems and the farms (or farming practices) need to be completely redesigned. Many large municipal sewage collection systems, for example, use the same pipes for their sewage and the storm drains. As a result, the sewage treatment plant may be quickly overwhelmed by any sizable rainfall forcing the entire runoff to be diverted into the receiving waters at such times. The long-term solution may require a complete restructuring of the existing collection system--an extremely expensive and awkward process which in many localities could require the excavation of nearly every street.

Thus, the prognosis is that new industrial installations, new towns, new structures will generally be able to meet the environmental standards, although the battle to determine what these standards should be and how they should change over time can be expected to be a continuous and often raucous one. As for the retrofitting, some has already occurred, some will occur in the near future, but many of the very difficult large-scale problems are likely to be resolved relatively slowly requiring perhaps 25 to 50 years, or even more in some instances.

Over the long term of our perspective even these retrofit problems appear to be susceptible to solution. The technology required for pollution control is in its infancy today. It is difficult to believe that after a hundred or more years the ability to control pollution adequately will be beyond our capability. The unfortunate legacy from the past has been the prolonged lack of concern with these problems, not the lack of an inherent ability to deal with them.

Of course we are implicitly assuming that technical progress will be sufficient to reduce the principal disturbances to the environment that otherwise would follow increases in population, food and industrial production. Considerable skepticism exists--especially among anti-growth advocates--about the inherent ability of technology to accomplish this end at less than prohibitive costs. Our investigation has led us to the conclusion that, despite the strong interaction among these key sectors, continued growth is feasible far beyond the limiting assumptions in this chapter while, on the average, the environment is steadily improved. This feasibility is found to depend only upon the continuation of technical innovation and an adequate desire within societies to accept the

associated costs. These costs may be large but are unlikely to be so large as to restrain a reasonable rate of economic growth over the long term.

6. Environment: Long Term

Unfortunately we cannot have the same kind of confidence that long-term or remote environmental dangers can be avoided, or corrected if they should occur. If we consider the possibility that a catastrophic irreversible process might be unwittingly set into motion, there is no way to estimate its likelihood. The recent concerns about the destruction of the ozone layer, the potential for atmospheric overheating from excessive carbon dioxide emissions or the triggering of climatic changes by excessive thermal emissions are examples of some surprises which have arisen out of mankind's expanding impact on natural processes. Although the ozone layer effect appears to be better understood and under reasonable control the potential for climatic changes is still obscure.— The greatest threats, however, may lie in phenomena which have not yet been observed or have not yet occurred. Imaginative scenarios have suggested mutated viruses against which there is no natural defense, thermonuclear catastrophes--both direct and indirect--and possible contamination by "bugs" imported from other planets.

Such potential problems may plague us from now on. We need to worry about these possible surprises and learn how to become aware of them early on in order to monitor them while solutions are sought. Of course, there is no reason to anticipate an inevitable catastrophe of our own making. More likely, in our judgment, are potential catastrophes that can be averted by appropriate action once the possibilities are noticed.

But attention to the formulation of possible problems and methods of obtaining timely evidence to cope with them probably will, and certainly should, be formally institutionalized. Debate on these long-range issues would thereby be stimulated and the scientific community made sensitive to the conceptual problems. We anticipate that within 50 years our ability to understand long-term environmental processes will have greatly--perhaps awesomely--increased. In 100 or 200 years our ability not only to understand but to control such processes could become quite impressive.

The urge for economic growth is so strong in most of the world today that worries about unknown possible long-term catastrophes will not be sufficient to change the course or even alter it much. Attempts to justify a no-growth concept on this basis appear to be highly unrealistic. What might be feasible is the establishment of a permanent study group, perhaps under U.N. auspices, to formulate not only the technical approaches to these problems but the ways to cope with such problems if international cooperation is required--as may well be the case for those involving climatic changes, for example. International cooperation is not always attainable. Perhaps under catastrophic threats it would be. Some advance thinking in this area would not be amiss.

7. Socio-Economic Projections

To return to our surprise-free scenario we have found that a reasonable physical basis exists for projecting a larger, but stabilizing, population in a growing world which can cope with the problems of energy, materials, food and environmental disturbance. This implies that the more important future problems will be the less tangible ones which are

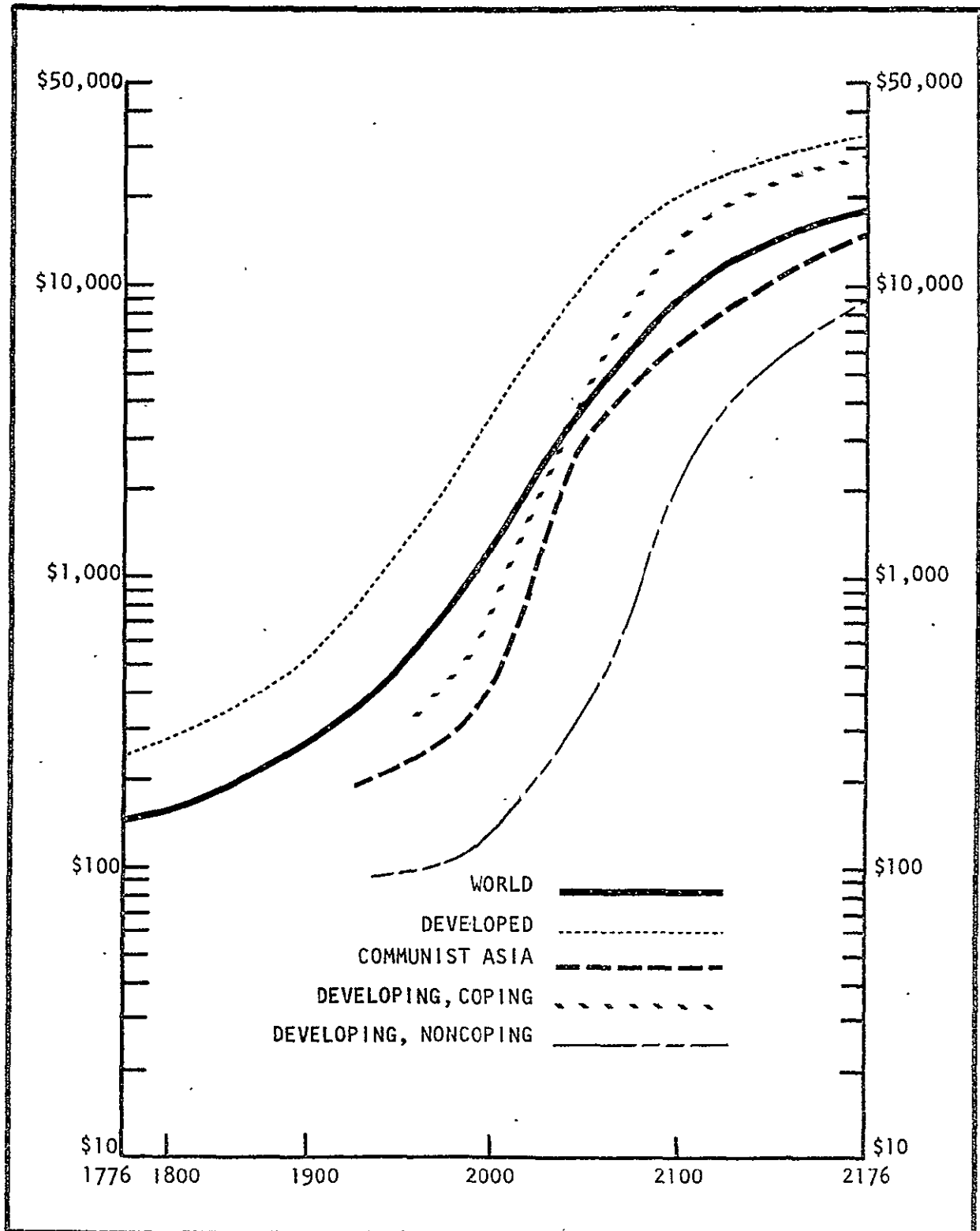
related to social and political changes, such as changing concepts of an equitable distribution of wealth or income.

Although realistic long-range socio-political projections are more tenuous to make--that is, very unlikely to be correct--they also tend to appear reasonably plausible, since generally only the clearly implausible can be ruled out. (Even this is suspect since the implausible seems to have happened regularly in recorded history.) Our choice, which we also take pains to describe as plausible, conceives of a growing world (described earlier in terms of population and GWP) that becomes relatively much more egalitarian in income distribution over the next 200-year period. This result (Figure 2) shows, for example, that the present 50 to 1 income disparity between the wealthiest nations and the poorest ones shrinks to about 9 to 1 over this period. The implication is that all nations become industrialized or post-industrialized during that interval and that poverty as we now know it is eliminated. Although economic aid might be a factor in this transition we argue that more traditional forces are better able to accomplish this change. The gap closes in part because the population of the wealthier nations are unwilling to work as hard as those of the poorer ones. As they come to depend increasingly upon the labor of the poorer nations they are gradually forced to offer them a greater share of the income. Other relevant factors in this economic change are projections of an increasing ability to transfer technology, growing tourism, increasing national security, and relatively stable governments.

Thus, our surprise-free scenario depicts a rather benign world, relatively free of violent conflict, growing moderately at first but

Figure 2

GROSS WORLD PRODUCT PER CAPITA, 1776-2176
(IN 1975 DOLLARS)



slowing down substantially over time with wealthier countries usually growing less than the poorer ones. It is a stable world with relatively stable nations and boundaries. Customs change as the affluent devote more time to leisure and artistic pursuits. The less affluent strive harder to attain the model of the affluent.

Our subsequent scenarios will be variations of this one and will be explored for their potential impact on the development and exploration activities in space.

Chapter III

POTENTIAL 21ST CENTURY SPACE DEVELOPMENTS

A. Some Early 21st Century Technologies

As will be discussed in more detail later it is possible that most of the developed world could become relatively hostile to science and technology. By blaming it, for example, for the dangers that it has unleashed (nuclear weapons, pollutants, hazardous chemicals, etc.) it can be claimed that technology is sure to create more harm than good and should either be stopped or severely controlled. Whatever the outcome of any such restrictive attempts it appears clear that enough momentum exists in current technological efforts that a surprise-free projection into the early 21st century would very likely include the developments shown in Table 6. Some remarks are in order about this table.

1. The recent interest and anticipated expenditures for the development of alternative energy sources almost guarantees the achievement of inexpensive and inexhaustible supplies early in the 21st century. The oil embargo of 1973 will be long remembered as a particular vulnerability that must be eliminated. Energy may not become cheap again, but it certainly need not be expensive. Indeed, the technological community can not rest until this is true. Because there is no fundamental reason why clean energy from relatively inexhaustible sources need be expensive, and because a large number of alternatives are being simultaneously pursued on a worldwide scale, among knowledgeable observers only a very pessimistic conservative or a neo-Malthusian advocate would be apt to dispute this conclusion. Moreover, by coupling new energy alternatives with efficient utilization practices it may even be possible that the effective price of energy may become quite

. Table 6

SOME EARLY 21ST CENTURY TECHNOLOGIES

1. INEXPENSIVE AND INEXHAUSTIBLE ENERGY SOURCES
2. POLLUTION-"FREE" INDUSTRIES PLUS IMPROVED RECYCLING
3. LARGE ADVANCES IN DRILLING AND MINERAL EXTRACTION
4. LARGE-SCALE UNCONVENTIONAL AGRICULTURE AND ARTIFICIAL FOODS
5. SUBSTANTIAL MATERIALS PROGRESS IN FIBERS, FOAMS, COMPOSITES, CERAMICS, CRYSTALS, POLYMERS, ADHESIVES
6. ULTRASENSITIVE SENSORS (SEE TABLE 7)
7. HUMAN-MACHINE COMMUNICATIONS
 - LARGE IMPROVEMENT FACTORS IN HARDWARE BY YEAR 2000
 - . OPERATING SPEED 10^7 - 10^3
 - . STORAGE CAPACITY 10^5 -- 10^{10}
 - . RELIABILITY 10^3 --?
 - . INFORMATION TRANSFER RATE.. 10^3 -- 10^5
 - SOFTWARE IMPROVEMENTS
 - . DATA COMPRESSION 2--1000
 - . PROGRAMMER PRODUCTIVITY ... 10--100
 - . VOICE COMMUNICATION ?
 - . AUTOMATIC PROGRAMMING ?
8. AUTOMATION: IMPROVED MACHINES
TELEOPERATORS
ADVANCED ROBOTS
INTELLIGENT ROBOTS
9. IMPRESSIVE ADVANCES IN GENETICS AND MEDICINE
10. "EXPONENTIAL GROWTH" IN SPACE-BASED COMMERCIAL VENTURES

inexpensive--or even cheap--once again. The effective price, of course, means the energy cost to perform the required task--heat the building, drive 100 miles, make a ton of steel, light up the office, launch a satellite, etc.

2. Pollution-"free" industries and improved recycling are obviously symbiotic. A major trend in industrial research today is to convert pollutants into resources. Sulfur is more and more being recovered in the form of useful by-products rather than emitted in noxious fumes. Low levels of metallic compounds in liquid wastes are now being recovered, thereby reducing pollution and recycling the valuable minerals. Urban wastes are being transformed into fuel and mineral resources. These few examples illustrate recent technological trends which we anticipate will soon revolutionize the current concerns about the ability of science and technology to reduce pollution and recycle effectively. By any reasonable historical measure the response to society's demands for an improved environment has been rapid and effective. Clearly as long as society demands it (and is willing to pay the costs involved) this trend will continue.

3. Within the last three years at least six novel or revolutionary design concepts for new drill bits have been announced. Yet the bit is only one part of the drilling process that is being improved. Other improvements in exploration and extraction industries are being made through the use of processed LANDSAT data, new downhole sensors, the application of computers to the mapping of geophysical structures, and the development of technology for deep sea mineral recovery. Currently there is little doubt that progress in the extractive industries will soon make exploration for

petroleum possible at almost any ocean depth, as well as the recovery of the mineral bearing nodules on the deep sea floor. The recent concern about adequate supplies of energy and minerals from secure sources has been coupled with powerful advanced technologies to effectively guarantee extraordinary progress in extractive industries over the next decade or two--perhaps for much longer.

4. We observed earlier in discussing future world food requirements that many avenues to unconventional agriculture and artificial foods have been opened and are now commercial, although many are not yet on a large scale. But the trend seems clear. Single-cell protein is being widely used as a supplementary animal food and is now manufactured on a large scale. The industry has predicted that within a decade the purity of the product will meet existing standards for human consumption and at no more than half the cost of competing protein rich foods (e.g., soybeans). Scientifically controlled growth chambers now exist on a commercial scale with yields in vegetable crops from 10 to 100 times greater than that from conventional agricultural land. These chambers are capital intensive year-round 24-hour operations. Their principal competitive determinant appears to be related to a single technical problem: how efficiently can energy be converted into the light frequencies which produce photosynthesis. This is the kind of problem in which a major breakthrough can occur in any year. We would be surprised if it hadn't happened by the year 2000. The nutrient film technique developed in England by the Glasshouse Crops Research Institute is used to grow vegetables in thin polyethylene troughs, without soil. This technique has been spreading rapidly and its application to cereals is currently under investigation.

Iowa State University researchers have found a way to increase soybean yields from 30 to 60 percent by a carefully controlled application of foliar spraying.* Standard Oil Company of Indiana is now commercially producing tortula yeast, a food made from petroleum that has twice the protein value of beef.** Michigan State University scientists have found a chemical in alfalfa which increased the yield of a number of greenhouse crops from 10 to 40 percent and which may be applicable to conventional farming.***

There are a few examples of a very long list of promising new approaches to food production. The sum of the unconventional approaches to food production could become a major factor in food supplies even before the next century.

5. Partly in response to the requirements of the aerospace and other high technology industries and partly because of recent rapid advances in diagnostic instruments and computer aided analysis and design, unusually rapid advances have been announced in a wide variety of materials--some of which are indicated in Table 6. Fibers of graphite, plastics and glass are now stronger than high tensile steel. An "endless" parade of new foams are being used to provide improving rigidity and insulation (against heat, electricity, or shock) with a minimum of material. New ceramics are providing both extreme hardness and toleration of extremely high temperatures.

* The Wall Street Journal, February 13, 1976.

** The Wall Street Journal, September 24, 1975.

*** The New York Times, April 17, 1977.

Crystals of very high purity and uniformity in structure provide unusual properties which made possible such devices as microcomputers, lasers, and most recently light "pipes" for communications. Production of polymers has become a huge growth industry--especially in plastics--that is projected to continue for a long time. Lastly, a remarkable array of adhesives have effectively challenged the older techniques of bonding with welds, rivets and other fasteners.

The progress in materials has been so remarkable that in some instances we may reach the theoretical limit to such material properties as strength, hardness, and bonding by the end of the century. However, the potential for composites, geometric designs, and new materials with unusual properties appear to be almost endless. Progress in theoretical understanding of the properties of materials is becoming even more rapid with the aid of new analytical instruments combined with high speed computers. These improved materials have already contributed immensely to the development of space vehicles and satellites and are expected to make possible not only much lower propulsion costs but much greater effectiveness in a given payload weight.

6. The astonishing improvements which have been made and which are expected to be made in sensors (see Table 7) will have a tremendous impact on science and technology. In some cases, as can be seen, sensors have approached or reached the theoretical limit (minimizing noise levels, for example). In most cases, however, the potential for improvement is either open ended or very far from any such limits. Thus the kind of progress shown in Table 7 can continue well into the 21st century, or beyond. These kinds of improvements hold an immense potential for serving mankind in general and space development in particular.

Table 7

SOME FORECASTS FOR ULTRA SENSITIVE SENSORS

	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
MICROWAVE RADIOMETERS				
NOISE TEMP. (°K)	2000	300	30	30
APERTURE (METERS)	1	2	10	40
RADIO TELESCOPE:				
SENSITIVITY AT 1-GHZ	1	.02		.01-.001
RADAR RESOLUTION, FROM EARTH				
ORBIT (METERS)	5	3½	2	1
SPACE TELESCOPE:				
APERTURE (CM.)	50	200		350-450
LASER ABSORPTION SPECTROMETER,				
ABS. COEFF.	4	10	12-100	10 ² -10 ⁴
MULTI-SPECTRAL IMAGERS,				
RESOLUTION (MICRO-RAD.)	100	25	10	7
SOLID STATE CAMERA (CCD)				
RESOLUTION (NO. OF ELEMENTS,				
MILLIONS)	--	1.1	5-7	11-30
PHOTON SENSITIVITY				
(MICRO-JOULES/M ²)		.8	.3	.2
ELECTRON SENSITIVITY				
(MICRO-JOULES/M ²)		.02	.01	.008
X-RAY TELESCOPE (20-300 K.E.V.)				
SENSITIVITY	1	.2	.03	.006
X-RAY SPECTROMETER (20-300				
K.E.V.) SENSITIVITY	4	.2	.01	.001
SUPERCONDUCTING MAGNETIC				
SPECTROMETER, INDEX	1.5	7-8	25-50	90-250
MAGNETS (KG. PER KILOGAUSS)	1.5	.5	.1	.04
GRAVITY GRADIOMETER	1	.01	.001	.001

SOURCE: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, A FORECAST OF SPACE TECHNOLOGY, 1980-2000, SP-387 (WASHINGTON, D.C.: SCIENTIFIC AND TECHNICAL INFORMATION OFFICE, JANUARY 1976). THIS TABLE IS AN ADAPTATION AND PARTIAL SUMMARY OF SOME OF THE DATA AND FORECASTS PRESENTED.

7. Progress in computers, already awesome, is expected to continue through this century, at least. Table 6 shows some current projections for hardware as well as for software which is more difficult to project. The degree to which the computer will change society can only be immense. Very likely the impact of present computer technology on the world is far from being understood since there has not been sufficient time for the full impact to be felt--a process which would take at least several decades more even if computer development itself were stopped. However, in a few decades computers themselves will be a thousand, or even a million, times more effective--depending on the applications. Today it is probably not possible to understand, even qualitatively, the way that the world's societies will be affected by the applications of computers over a century or more.

8. Some of the potential applications of computers to automation can be understood--to a degree. Microprocessors are destined to appear in our automobiles, appliances, telephones, wrist radios, as well as our factories and commercial establishments. For remote maintenance (such as in outer space) teleoperators will probably become common. The recent Viking landers are probably the world's most advanced robots to date. This can only be the beginning of robotry. That such robots can become much more "intelligent" is not doubted in the sense of machines with limited learning capabilities. Whether they can eventually become intelligent in the human sense is an ongoing, unresolved debate among scientists specializing in the field.

9. Perhaps the most spectacular scientific advances have and, in the near term, will continue to occur in microbiology. The implications

for genetic understanding and the potential application to genetic control, and the prevention and cure of diseases--physical, emotional, and mental (if these are proper categories)--is truly exciting. Certainly, there is a reasonable chance that all bacterial and viral diseases can be prevented or rapidly cured before too long--perhaps even by this century's end. Progress in this field has been intimately associated with progress in the sciences of physics, chemistry, and biology, and in the technologies of computers, analytical instruments, sensors, and pharmacology. The remarkable integration has led to astonishing advances which appear to be only the beginning of much greater discoveries and applications to come.

10. For future progress in space development--especially for manned operations in space which are currently visualized as space laboratories, permanent space bases, space industries, colonies in orbit or on planetary bodies, and space explorers--all of the above technological developments are very important. The results of the expected growth in space industrialization can be vastly different depending upon whether the annual growth rate is 2, 5, 10, or 20 percent. The 2 percent figure is barely interesting: the 20 percent figure would soon spawn results like those of science fiction. (To mention exponential growth alone leaves obscure the major element--the doubling rate. This will depend upon many factors in addition to the technologies. Some of these will be incorporated in our subsequent scenarios and, by their effect on the doubling rate, lead to vastly differing outcomes.)

The progress which has occurred in space technology in the past and that which might be expected to occur over this century under reasonable optimistic conditions (adequate funding and/or good luck) are illustrated

in Table 8. The data for this table have been taken from NASA sources, principally from the 1975 Outlook for Space study. These projections generally are based upon careful evaluations by competent scientists and are as likely to be understated as overstated. Where a range is given in the projected progress the principal consideration is the available funding. For example, to achieve the major reductions in launch costs would perhaps require \$10 billion for the development of a large capacity reusable unmanned vehicle. The principal implication to be drawn from the table is that some astonishing space developments are likely to occur within this century--developments that might even surprise technological optimists who are not specialists in space technology..

B. Space Industrialization (SI)

To many space scientists the industrialization of space, in the sense of manufacturing operations conducted in or beyond near-earth orbit, is certain to happen. Because of its embryonic nature its early growth rate is highly uncertain. Research and development on processes for future SI installations has been pursued in space as well as in earth laboratories for several years. The three Skylab launches were the first extensive manned R&D operations conducted in space that focused upon the SI concept. The results of these and subsequent efforts led Grumman's G. Harry Stine to claim that a third industrial revolution is about to start.*

* G. Harry Stine, The Third Industrial Revolution (New York: G. P. Putnam & Sons, 1975). Also, for a recent NASA study on the SI potential see Rockwell International, Space Division, Space Industrialization, Final, Part I: Technical Report, SD.77-AP-0076 (Rockwell International, July 15, 1977).

Table 8

PROGRESS IN SPACE TECHNOLOGY, PAST AND PROJECTED

SYSTEM	1960	1975	1990	2000
1. LAUNCH VEHICLE: PAYLOAD CAPACITY (LBS)	25	250,000	10^6 (REUSABLE)	2×10^6 (REUSABLE)
2. COMMUNICATION SATELLITE (CHANNELS)	15 (LOW ORBIT)	15,000 (SYNCHRONOUS)	100,000 (SYNCH)	10^6 (SYNCH)
3. COMM. (MARS TO EARTH) BITS/SEC	8	10^5	10^7	10^9
4. MAN DAYS/MISSION	.1	250	10^5	5×10^5
5. RESOLUTION (KM)	5 (LOW ORBIT)	.1 (LOW ORBIT)	.05 (GEOSYNCHRONOUS ORBIT)	.02
6. DATA STORAGE ABOARD SPACECRAFT	15 PAGES (.5 MEGABITS)	2,000 BOOKS (@ 300 PAGES) (20 GIGABITS)	1/2 LIBRARY OF CONGRESS (8,000 GIGA- BITS)	10 LIB. OF CONGRESS
7. ENERGY STORAGE (KW HRS/LBS)	.02	40	800	1200
8. ACTIVE CIRCUITS/IN. ³	4	120,000	5×10^8	$10^{10} - 10^{12}$
9. SPACE-BORNE COMPUTER SPEED (OPERATIONS/SEC.)	$.002 \times 10^6$	$.5 \times 10^6$	30×10^6	$100-1000 \times 10^6$
10. COST OF LAUNCHING (\$/LB TO EARTH ORBIT)	10,000	250	25-50	10-30
11. POSITION ERROR (METERS)	1,000	50	.1	.02
12. FAILURES/HR/M. BITS	10^{-2}	10^{-4}	10^{-6}	$10^{-7}-10^{-8}$

THIS DATA IS ADAPTED FROM VARIOUS NASA SOURCES--PRIMARILY FROM THE REFERENCE
GIVEN ON TABLE 7.

Why industrialize space? The answer must be essentially economic. There must be important commercial operations which can be done only in space or which can be done better in space. That is, the space environment has a number of exploitable advantages that are unavailable or very costly on earth. The principal ones now known are listed in Table 9.

These advantages can be impressive. They may make possible a very large array of new products and processes of great commercial value. Designs already exist, for example, for Solar Satellite Power Systems (SSPS) which can beam microwave power to earth in essentially unlimited quantities from the inexhaustible and constant sun. This power is readily converted to electric power without polluting the air or water. The estimated cost at present is not competitive but, as we shall see, this could change relatively soon.

High vacuum industries on earth are among the most rapidly growing sectors, a trend which is almost certain to continue as high vacuum is employed in nearly all electronic as well as many other high technology industries. Providing and maintaining vacuum in industries is expensive. In space, however, very high vacuums, unattainable on earth are trivially easy to arrange and can be "permanent."

Weightlessness may be the most interesting, perhaps the most important property of space. It is the one continual property of every space orbit for which no parallel exists in daily human experience (beyond free fall which generally lasts less than one second). Space scientists are attempting to visualize the implications of the weightless environment and design processes which can use its advantages. Still this science, or art, is at best embryonic and is likely to remain so throughout most

Table 9

TEN ADVANTAGES OF OPERATING IN SPACE

1. SOLAR POWER (10 x RATE ON EARTH) PLUS U-V, X-RAYS, ETC.
2. UNLIMITED HIGH VACUUM (10^{-8} to 10^{-14} MM. HG. IN 300 MILE ORBIT)
3. AVOIDS PRESENT HAZARDS [E.G., QUAKES, STORMS (WIND, RAIN, HAIL,...), UNPREDICTIBLE TEMPERATURE CHANGES (DAILY, SEASONAL,...), LIGHTNING, FLOODS, VOLCANOES, INTRUDERS (HUMAN, INSECT OR MICROBE), CORROSION, POLLUTION, ETC.]
4. WEIGHTLESSNESS FACILITATES
 - A. SOME MANUFACTURING ACTIVITIES
 - B. CONSTRUCTION OF LARGE LIGHTWEIGHT STRUCTURES
 - C. RELIABILITY OF OPERATIONS
5. POTENTIAL RAW MATERIALS ON MOON AND ASTEROIDS
6. GOOD "VIEWS" OF EARTH AND OUTER SPACE FOR COMMUNICATION, OBSERVATION, POWER TRANSMISSION, AND OTHER APPLICATIONS
7. INFINITE HEAT SINK NEAR ABSOLUTE ZERO
8. LITTLE OR NO ENVIRONMENTAL, ECOLOGICAL OR "LOCALISM" ISSUES
9. MAY BE ENJOYABLE, HEALTHFUL, STIMULATING OR OTHERWISE DESIRABLE
10. RAPIDLY IMPROVING TRANSPORTATION AND INCREASINGLY USEABLE AND AVAILABLE INFRASTRUCTURE

IN ANY CASE A TRUE FRONTIER

of the century, even as it develops rapidly. Accordingly we have a great deal to look forward to because this phenomenon already promises to yield some exciting products and processes in future orbiting industries.

Many materials behave differently in a weightless condition. Liquids form perfect spheres which can be solidified, maintaining sphericity. Surface tension, usually a minor force compared to gravity, becomes a dominant one in space, making the contacts between liquids and solids act in "peculiar" manners. Gases behave differently. Hot air does not rise in zero-G, making it difficult to start a fire. A lit candle quickly snuffs itself out. Weightlessness means that structures a mile long can be made of thin metal foil without bending or breaking. Tiny bearings can control massive rotors.

These and many other novel properties of space have spawned a large array of potential applications for SI which is expected to take a large forward step after the space shuttle begins commercial operations in 1980. The early shuttle efforts, naturally, will concentrate upon R&D. However, there are already some indications that production of high purity pharmaceuticals and of silicon wafers for electronic circuits are likely to be among the earliest commercial developments. A longer list of some of the more promising early SI activities is shown in Table 10.

Perhaps the key point in Table 9 is the tenth one--that the transportation costs to space and back have dropped rapidly and can be expected to do so in the future. Indeed, as projected in Table 8, about a factor of 10 reduction in transport costs is possible by the end of the century. This projection is based upon a continued growing effort in space activities, represented by an expanding budget. As the transportation costs

Table 10

A SUGGESTIVE, BUT HARDLY EXHAUSTIVE, LIST OF
SPACE MANUFACTURING ACTIVITIES

1. VACUUM CAST ALLOYS AND VACUUM WELDS
2. HIGH-PURITY BIOLOGICALS AND NOVEL PHARMACEUTICALS
3. OPTICAL SYSTEMS - PARTICULARLY FOR LOW G - AND THIN FILM SURFACES
4. LARGE SHEET CONSTRUCTIONS
5. LARGE-SCALE VACUUM BASED SYSTEMS (E.G., CRYOGENIC, SUPER-CONDUCTING)
6. SPECIAL ELECTRONIC MATERIALS, INCLUDING PURE CRYSTALS
7. PROPULSION FUELS (AND SPACE CRAFT COMPONENTS) FOR FURTHER SPACE DEVELOPMENT
8. ULTRA HIGH STRENGTH FIBERS
9. PRODUCTS UTILIZING SPECIAL MINERAL FINDS: (E.G., WATER, TITANIUM, ALUMINUM)
10. POWER STATIONS FOR SOLAR ENERGY CONVERSION
11. 3-DIMENSIONAL INTEGRATED-CIRCUIT "CHIPS" FORMED FROM ZERO VACUUM MELTS
12. DELICATE INSTRUMENTS FOR ZERO-G USE (WHICH COULD NOT STAND HIGH STRESSES OF EARTH FABRICATION AND/OR LAUNCH)

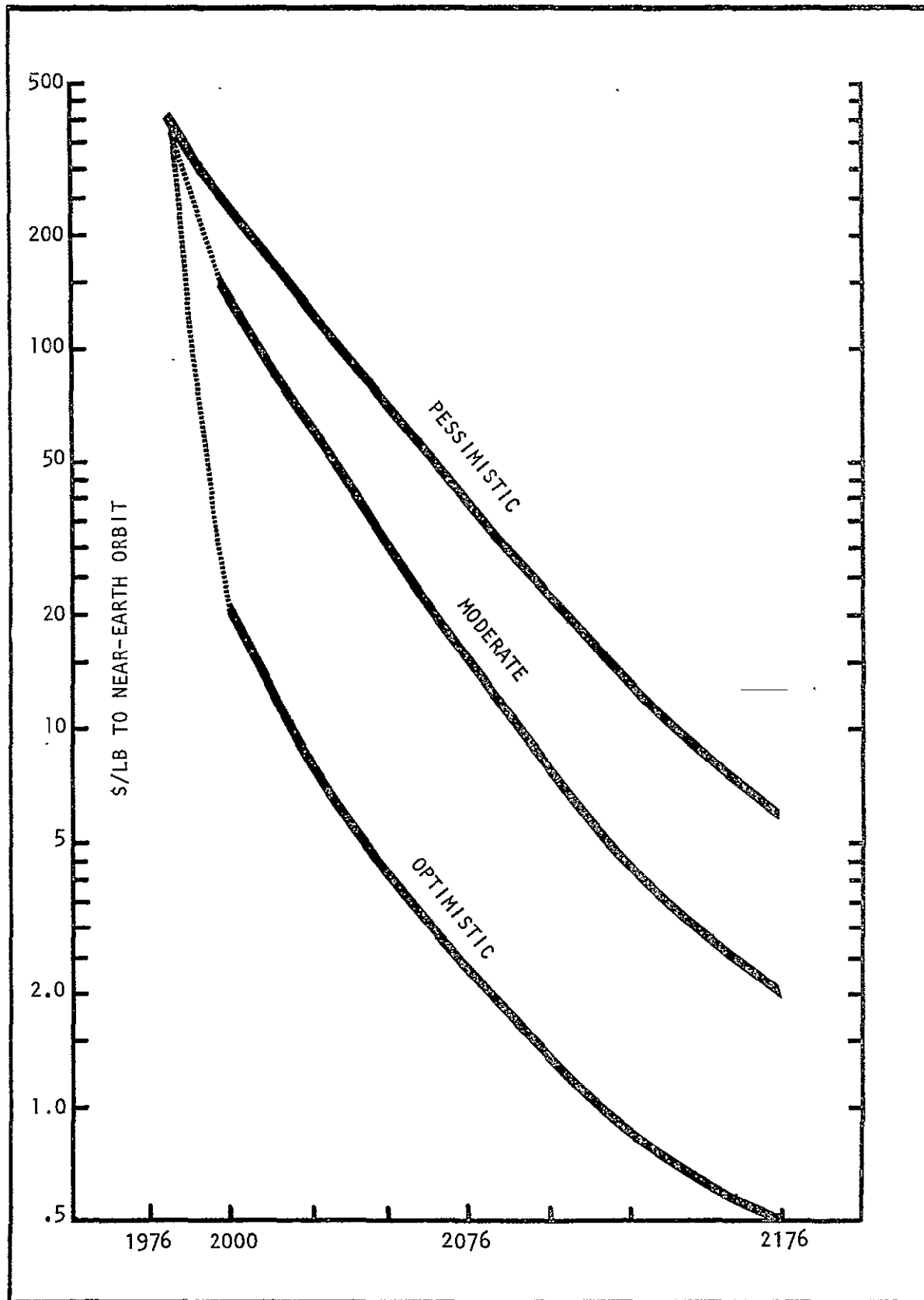
drop the number of viable SI products can increase very rapidly--at least up to the point where transportation is no longer the dominant factor. With the Space Shuttle the cost of transportation after 1980 is expected to be about \$300 or \$400 per pound for a round trip. This cost represents a substantial improvement but is still high. It will prevent the commercialization of many products and will restrict much required R&D until the next generation transportation system arrives.

We have projected far future space transportation costs along three modes: optimistic, moderate and pessimistic. These 200-year projections are given in Figure 3. After 200 years the optimistic view projects a cost of \$.50/lb. to near-earth orbit, about three times the cost of the minimum energy required--at current prices for electric power. The most conservative projection ends up at \$6/lb., only a factor of three better than what is believed to be feasible during this century. The actual path that these transportation costs follow may be the most important technical factor affecting the future developments in space.

The number of human beings involved in space industrialization will be strongly affected by transportation costs. The utilization of people requires the transport of housing facilities, food, air, water, and various paraphernalia for maintenance, communication, etc. As long as transportation is very expensive the SI effort must depend upon a very high degree of automation, including the use of compact teleoperators for maintenance adjustments, and/or process changes. The paucity of human attendants will reduce the operating flexibility substantially, but it will be a necessary phase of the evolving SI process.

Figure 3

TRANSPORTATION COSTS TO NEAR-EARTH ORBIT



ORIGINAL PAGE IS
OF POOR QUALITY

Table 11 .

APPLICATIONS SUMMARY AND RISK ESTIMATION

	RISK CATEGORY*		RISK CATEGORY*
<u>PERSONAL APPLICATIONS</u>		<u>GOVERNMENT APPLICATIONS</u>	
- Personal Communications Wrist Radio	I	<u>COMMUNICATIONS</u>	
- Emergency/Rescue Wrist Beacon	I	- Voting/Polling Wrist Set	I
- Personal Navigation Wrist Set	II	- Electronic Mail Transmission	I
- Voting/Polling Wrist Set	I	- Border Surveillance	II
		- Nuclear Materials Locator	I
		- Library Data Sharing	I
<u>CIVIC APPLICATIONS</u>		<u>OBSERVATION</u>	
- Disaster Communications Wrist Radio	I	- High Resolution Resources/Pollution Observatory	II
- All-Aircraft Traffic Control	I	- Water Level and Fault Movement Indicator	I
- Urban/Police Wrist Radio	I	- Atmospheric Temperature Profile Sounder	III
- Car Speed-Limit Control	I	- Forest Fire Detection	I
		- Ocean Resources Location	I
<u>INDUSTRIAL APPLICATIONS</u>		<u>SUPPORT</u>	
- Burglar Alarm/Intrusion Detection	I	- Passive Coastal Anti-Collision Radar	II
- Vehicle / Package Locator	II	- Night Illuminator	II
- 3D Holographic Teleconferencing	III	- Energy Delivery and Distribution (5 concepts)	IV
- Advanced T. V. Broadcast	I	- Energy Consumption Monitor	I
- Advanced Resources/Pollution Observation	I	- Aircraft Laser Beam Powering	IV
		- Nuclear Waste Disposal	II
<u>INTERNATIONAL APPLICATIONS</u>		<u>SCIENTIFIC APPLICATIONS</u>	
- Nation-Nation "Hot Lines"	I	- Astronomical Super-Telescope	IV
- Multinational Air Traffic Control Radar	I	- Interplanetary T. V. Link	II
- Small Terminal Intelsat Network	I	- Atmospheric Temperature Profile Sounder	III
- Earth Resources Data Sharing	I	- Ocean Resources and Dynamics Sensor	I
- Energy Distribution Relay	IV	- Water Level and Fault Movement Indicator	I
- U.N. Truce Observation Satellite	I		

* I-IV ARE LOW TO HIGH, RESPECTIVELY.

SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME I: EXECUTIVE SUMMARY, ATR-76(7365)-1, VOL. I (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 27.

C. Other Commercial Opportunities

An interesting study was produced recently by Bekey, Mayer, and Wolfe of the Aerospace Corporation offering a large number of conceptual designs for new space concepts that might be commercially feasible during this century. A summary of their potential non-military applications is given in Table 11 above. These concepts have been examined sufficiently to sketch out the engineering designs and to permit very rough cost estimates to be made. Each concept was assigned a risk rating from I to IV (low to high) and a time frame for installation. Of the 42 initiatives

given in the Aerospace Corporation report, four have been selected for illustration and are presented below as Figures 4, 5, 6, and 7. The list of potential practical developments in space can be expected to grow continuously, perhaps even exponentially, if the future funding of space development in the U.S. at least keeps pace with the national income. If the space budget is sufficient to permit an advanced transportation system which can deliver payloads to orbit at, say, \$50/lb. or less, then the development of commercial space-based services and products might become attractive enough to private investors to enable them to take much more initiative in their development and installation.

D. Future Space Program: Near Term

Any national space program must reconcile its many specific options with the available budget. NASA, which has been enduring a gradual budgetary squeeze for several years, has had to cut back and stretch out a number of its programs despite an enviable record of successful launches and accurate cost projections. Nevertheless every space engineer's hope is that a logical space development program can be designed with a gradually (or rapidly) increasing budget. One well conceived and well presented perspective on NASA's future program, for example, is given in a paper by Jesco von Puttkamer in the Journal of the British Interplanetary Society.^{*} This paper describes an evolving program in considerable conceptual detail, a program which gradually expands Man's occupancy of space from near-earth orbit to the outer planets, developing

^{*} Jesco von Puttkamer, "Developing Space Occupancy: Perspectives on NASA Future Space Programme Planning," Journal of the British Interplanetary Society 29 (1976): 147-173.

Figure 4

ADVANCED RESOURCES/POLLUTION OBSERVATORY (CO-1)

● PURPOSE

To provide high quality, multispectral earth resources and pollution data.

● RATIONALE

Integrated ERTS-like system, real-time data distribution to worldwide users, active sensors needed.

● CONCEPT DESCRIPTION

Active and passive sensors, large aperture, high, medium, and low resolution imaging obtained in multispectral region and radar. Data disseminated by laser link through relay satellite.

● CHARACTERISTICS

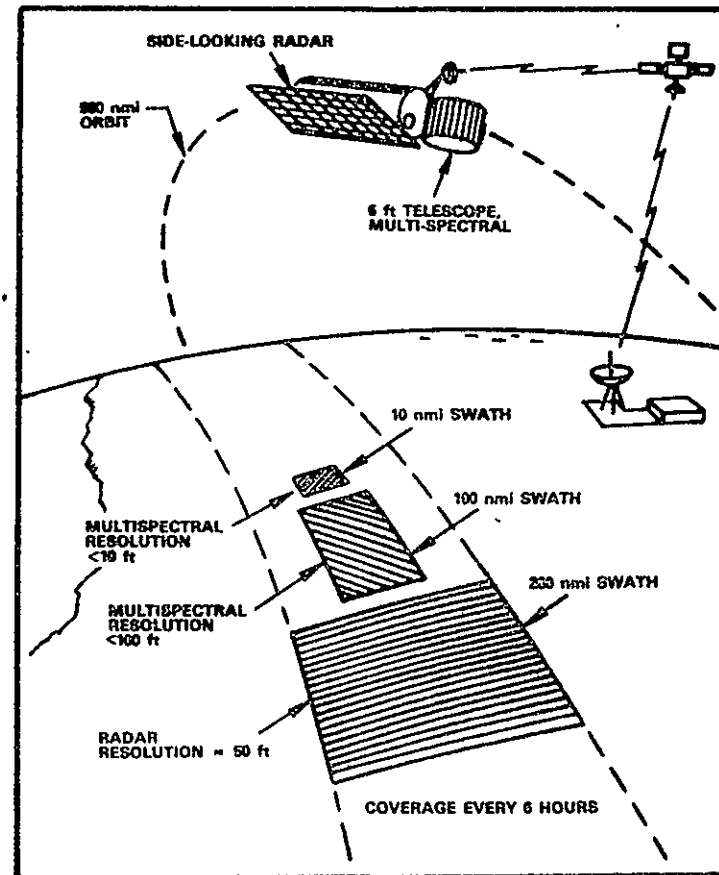
● WEIGHT	30,000 lb
● SIZE	10 x 60 ft
● RAW POWER	12 kW
● ORBIT	500 nmi sun synch.
● CONSTELLATION SIZE	1
● RISK CATEGORY	1 (Low)
● TIME FRAME	1985
● IOC COST (Space only)	350 M

● PERFORMANCE

Multispectral resolutions varying from < 10 to < 100 ft obtained worldwide.

● BUILDING BLOCK REQUIREMENTS

● TRANSPORTATION	Shuttle and tug
● ON-ORBIT OPERATIONS	Shuttle attached manipulator, servicing stages
● SUBSYSTEMS	Guidance and navigation; attitude control; transmitter
● TECHNOLOGY	Large radar antenna; high power tubes and modulator; LSI data processor
● OTHER	None



SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME III: DETAILED DATA - PART I: CATALOG OF INITIATIVES, FUNCTIONAL OPTIONS, AND FUTURE ENVIRONMENTS AND GOALS, ATR-76(7365)-1, VOL. III (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 10.

Figure 5

COASTAL ANTI-COLLISION PASSIVE RADAR (CO-9)

● PURPOSE

Inexpensive and lightweight radar for all surface vessels - navigation; collision avoidance.

● RATIONALE

Conventional radar too expensive and interference prone. Pleasure craft usually denied radar benefits.

● CONCEPT DESCRIPTION

Illuminate seacoasts with scanning microwave beams from space. Scanning receiving antennas on boats obtain range and angle data on hazards.

● CHARACTERISTICS

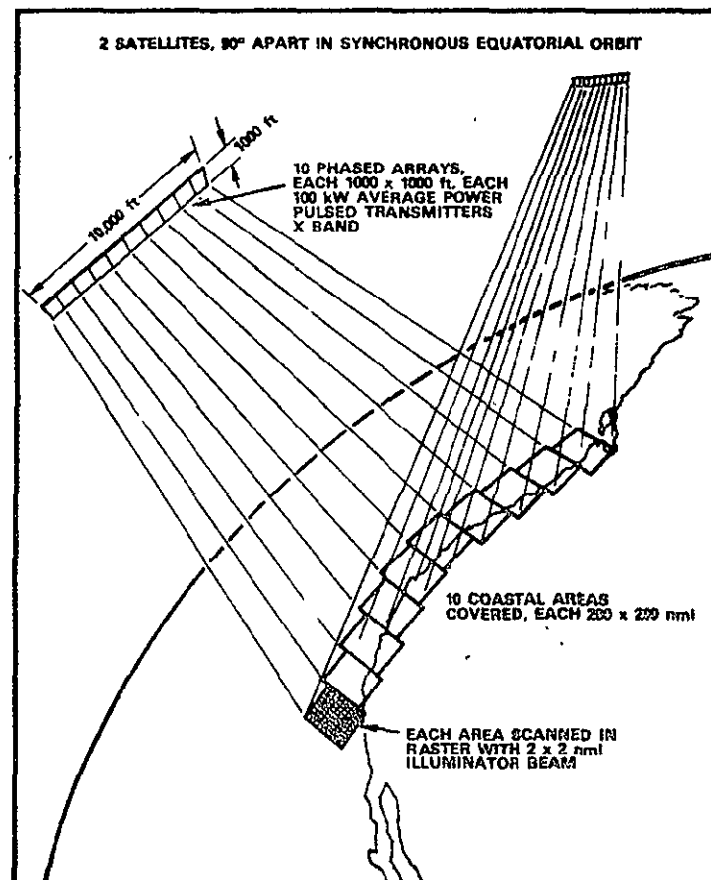
● WEIGHT	2,000,000 lb
● SIZE	1,000 x 10,000 ft
● RAW POWER	3 MW
● ORBIT	Synch. Equat.
● CONSTELLATION SIZE	2
● RISK CATEGORY	11 (Medium)
● TIME FRAME	1995
● IOC COST	10 B

● PERFORMANCE

Relative location of all objects $>100 \text{ m}^2$ within 12 nmi range. 100 x 300 ft accuracy in 50° sector. 3 x 0.5 ft antenna in vessel. Unlimited number of users.

● BUILDING BLOCK REQUIREMENTS

● TRANSPORTATION	LLV and large tug or large SEPS
● ON-ORBIT OPERATIONS	Automated or manual servicing unit; assembly in orbit
● SUBSYSTEMS	Structures; attitude control; antenna; power
● TECHNOLOGY	Large adaptive microwave antenna; high power transmitters; prime power source.
● OTHER	



SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME III: DETAILED DATA - PART I: CATALOG OF INITIATIVES, FUNCTIONAL OPTIONS, AND FUTURE ENVIRONMENTS AND GOALS, ATR-76(7365)-1, VOL. III (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 18.

Figure 6

ATMOSPHERIC TEMPERATURE PROFILE SOUNDER (CO-11)

● PURPOSE

To measure actual profiles of temperature in the atmosphere.

● RATIONALE

Weather prediction requires knowledge of temperature profiles, as well as other phenomena.

● CONCEPT DESCRIPTION

Pulsed laser vibrationally excites CO₂ or H₂O molecules. Subsequent rotational transitions in the millimeter wave spectrum show temperature dependence which is measured by ratio of energy in several lines.

● CHARACTERISTICS

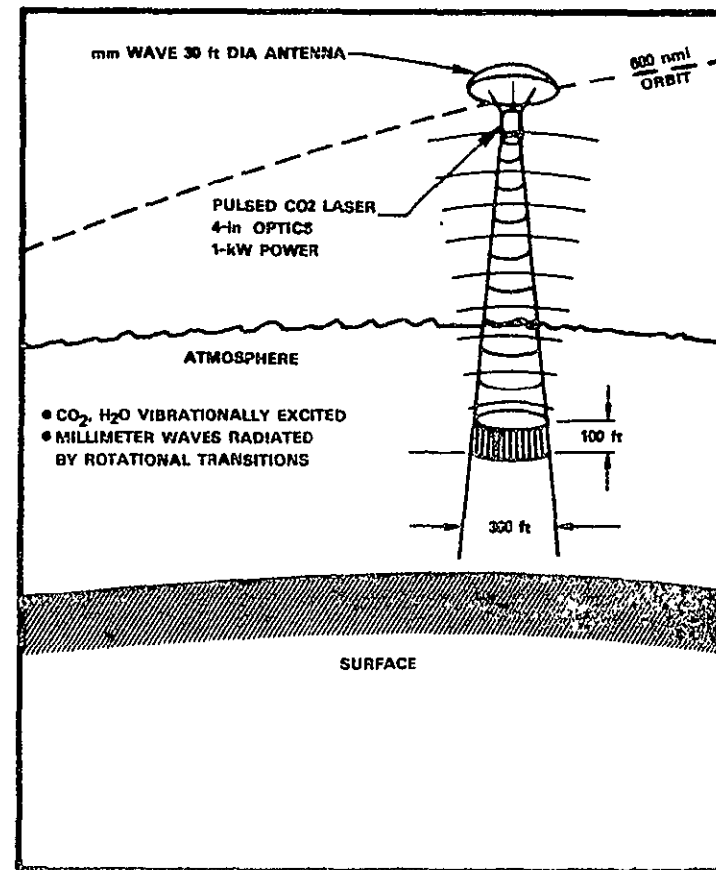
- WEIGHT 4000 lb
- SIZE 30-ft dia antenna
- RAW POWER 5 kW
- ORBIT 600-nmi polar
- CONSTELLATION SIZE 4
- RISK CATEGORY III (Medium)
- TIME FRAME 1990
- IOC COST (SPACE ONLY) 250 M

● PERFORMANCE

Entire atmosphere measured, with resolution of 300 ft horizontally and 100 ft vertically, every four hours. Emission lines and signal strength imprecisely defined at present.

● BUILDING BLOCK REQUIREMENTS

- TRANSPORTATION Shuttle and tug/IUS
- ON-ORBIT OPERATIONS Automated service unit/Shuttle-attached manipulator
- SUBSYSTEMS Antenna, laser, attitude control
- TECHNOLOGY Laser, power dissipation, antenna, pointing, sensitive heterodyne receiver
- OTHER



SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME III: DETAILED DATA - PART I: CATALOG OF INITIATIVES, FUNCTIONAL OPTIONS, AND FUTURE ENVIRONMENTS AND GOALS, ATR-76(7365)-1, VOL. III (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 20.

Figure 7

PERSONAL COMMUNICATIONS WRIST RADIO (CC-9)

● PURPOSE

To allow citizens to communicate through exchanges by voice, from anywhere.

● RATIONALE

Mobile telephones are desirable, but should be wrist worn. Uses include emergency, recreation, business, rescue, etc.

● CONCEPT DESCRIPTION

Multichannel switching satellite and wrist transmitter-receivers connect people anywhere to each other directly or to telephone networks. Analog or vocoded voice used.

● CHARACTERISTICS

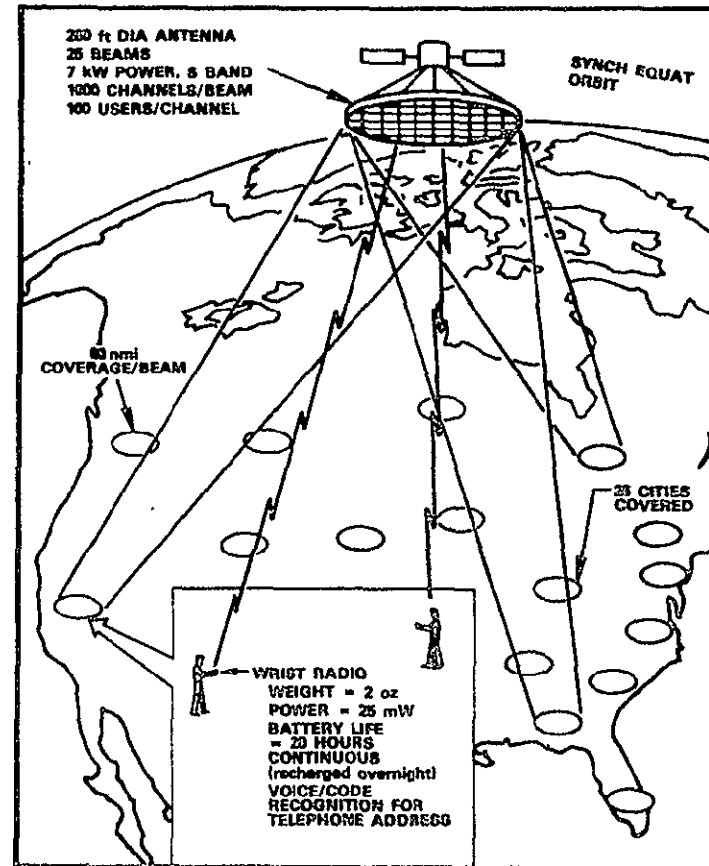
● WEIGHT	16,000 lb
● SIZE	200 ft dia antenna
● RAW POWER	21 kW
● ORBIT	Synch. Equat.
● CONSTELLATION SIZE	1
● RISK CATEGORY	I (Low)
● TIME FRAME	1990
● IOC COST (SPACE ONLY)	300M

● PERFORMANCE

25,000 simultaneous voice channels, each shared by up to 100 users: 2.5 million people communicate by normal voice.

● BUILDING BLOCK REQUIREMENTS

● TRANSPORTATION	Shuttle and large/tandem tug or SEPS
● ON-ORBIT OPERATIONS	Automated or manual servicing unit; assembly on orbit
● SUBSYSTEMS	Attitude control; antenna; processor; repeater
● TECHNOLOGY	Large multibeam antenna; multi-channel repeater; LSI processor, multiple-access techniques
● OTHER	Wrist transceiver, LSI technology



SOURCE: I. BEKEY, H.L. MAYER AND M.G. WOLFE, ADVANCED SPACE SYSTEM CONCEPTS AND THEIR ORBITAL SUPPORT NEEDS (1980-2000), VOLUME III: DETAILED DATA - PART I: CATALOG OF INITIATIVES, FUNCTIONAL OPTIONS, AND FUTURE ENVIRONMENTS AND GOALS, ATR-76(7365)-1, VOL. III (EL SEGUNDO, CALIFORNIA: THE AEROSPACE CORPORATION, APRIL 1976), P. 32.

the required transport, communication, manufacturing systems, and space colonies as they are needed. Many of the costs of 20th century subsystems are estimated by von Puttkamer, although the full required annual space budgets are not projected. His concepts and schedules would be compatible with the early developments of our Optimistic Scenario and in part with our Moderate Scenario.

Perhaps the most prolific designer of potential space industrial systems has been Dr. Krafft Ehrlicke of Rockwell International. A good review by Ehrlicke of his contributions is available in recent Congressional Hearings entitled Future Space Programs 1975.^{*} Ehrlicke offers a complete package with philosophical justifications, original space concepts, transportation system requirements, engineering designs, and cost estimates. Many of his concepts are explicitly or implicitly included in the Optimistic Scenario. Many other excellent contributions by other space scientists are found in the above reference; these have furnished us with considerable guidance.

Probably the single most useful guide to NASA's future course is its Outlook for Space report.^{**} This thorough 1975 study examines the technological options and the socio-political milieu in which NASA expects to operate over the balance of this century. It appears that NASA's near-term program will be oriented more heavily toward earth applications satellites and R&D for future space industrialization and that this trend will probably continue for some time. This does not imply that space

^{*} U.S., Congress, House, Committee on Science and Technology, Future Space Programs 1975, A Compilation of Papers prepared for the Subcommittee on Space Science and Applications. 94th Cong., 1st sess., September 1975, Committee Print, 2: 59-65. (See, also, footnote on p. 74.)

^{**} National Aeronautics and Space Administration, Outlook for Space, SP-386 (Washington, D.C.: Scientific and Technical Information Office, January 1976).

science and exploration will be ignored, but that their share of the budget will be under some stress--an experience which can be quite painful when the budget is not expanding. Over the very long term, however, there appear to be many important factors which will determine the nature and size of the space development effort. These are considered in the next section.

E. Future Space Program: Long Term

The major factors which we believe will affect the pace of future space developments are listed in Table 12.

The first factor or "key" is that future space technology must be successful. The main specific item is a sharp reduction of the costs of sending men and materials into orbit. As mentioned earlier many scientists believe that straightforward R&D can reduce transport costs by about a factor of 10 by the end of this century. This outcome requires no great breakthroughs in basic propulsion systems. It is based upon the use of hydrogen-oxygen engines, larger reusable vehicles, and evolving designs optimized through computer-assisted analysis. The estimated factor of 10 would probably apply only to automated "freighters" whose acceleration would not be limited by the presence of human beings. During the balance of this century manned operations in space projects will probably be minimized. In any event the bulk of the payloads sent to space will not be human beings for several decades. The above transport costs can be greatly reduced if and when metallic hydrogen becomes available as a fuel or if practical techniques are developed to transmit high levels of power to the vehicle from the ground or from space during its ascent. Both of these developments are conjectural at present.

Table 12

KEYS TO LONG-TERM DEVELOPMENTS IN SPACE

1. SUCCESSFUL TECHNOLOGY
 - DECLINING TRANSPORTATION COSTS TO NEAR-EARTH ORBIT
 - EFFICIENT SPACE TUG ENGINES
 - ORBITING SPACE BASES AND PROFITABLE INDUSTRIES
 - RELIABLE "INTELLIGENT" ROBOTS
 - LUNAR COLONIES
 - PLANETARY SPACE STATIONS AND COLONIES
2. TOURISM
 - "INEXPENSIVE" SAFE TRANSPORT
 - SPACE HOTELS, HOSPITALS, CONVENTION CENTERS
 - EXCITING JOURNEYS
3. POSITIVE HEALTH CONSIDERATIONS
 - PHYSICAL--MENTAL--EMOTIONAL
 - LONGEVITY
4. INTERACTIONS WITH EARTH
 - INCREASING PRIVATE INVESTMENT
 - NATIONAL ENTHUSIASM
 - INTERNATIONAL COOPERATION
5. QUALITY OF "FRONTIER-LIFE"
 - FAVORABLE SOCIAL DYNAMICS
 - BENIGN POLITICS
 - RAPID ECONOMIC GROWTH

Without going into detail about the other items on the technology list we can, with considerable confidence, assert that the indicated developments are likely to be successful. The history of space technology, indeed of high technology generally, supports this conclusion in addition to the fact that the path toward such solutions is reasonably well understood. Space scientists are confident that the near-term goals can be met, but they cannot know whether the desire to attain these technological goals is sufficient to create the funding. The space "freighter" or a VTOVL-SSTO-HLLV (translated: Vertical Take Off and Vertical Landing, Single State To Orbit, Heavy Lift Launch Vehicle) as indicated earlier, might require about \$10 billion just for the R&D. With such a large investment it is clear that a large-scale launching program must be contemplated, else the capital requirements could not be amortized without making the launch costs prohibitive. The full array of vehicles required for an advanced space transportation system would need to include space tugs for transferring payloads to new orbits or to other planetary bodies. Also, landing systems will be required if these payloads are to be delivered to planetary surfaces. These additional vehicles generally would be smaller than the freighter. Preliminary designs for many of them have already been drawn.

Space tourism appears to be an inevitable follow-on to the indicated technological developments. Once the costs of space launching have been sufficiently reduced and safety is sufficiently assured the interest in space travel or tours undoubtedly will lead to an accommodating industry. This industry, initially, could only cater to the wealthy as a space tour even around the year 2000 might cost roughly \$100,000 for a few days,

perhaps a week, in orbit. However, if transportation costs continue to fall and personal income continues to rise as we have projected, then space tourism beginning in the 21st century can become a unique industry that appears to have a potential to continue growing for well over the interval of this study; that is, beyond 2176, the U.S. Quadricentennial.

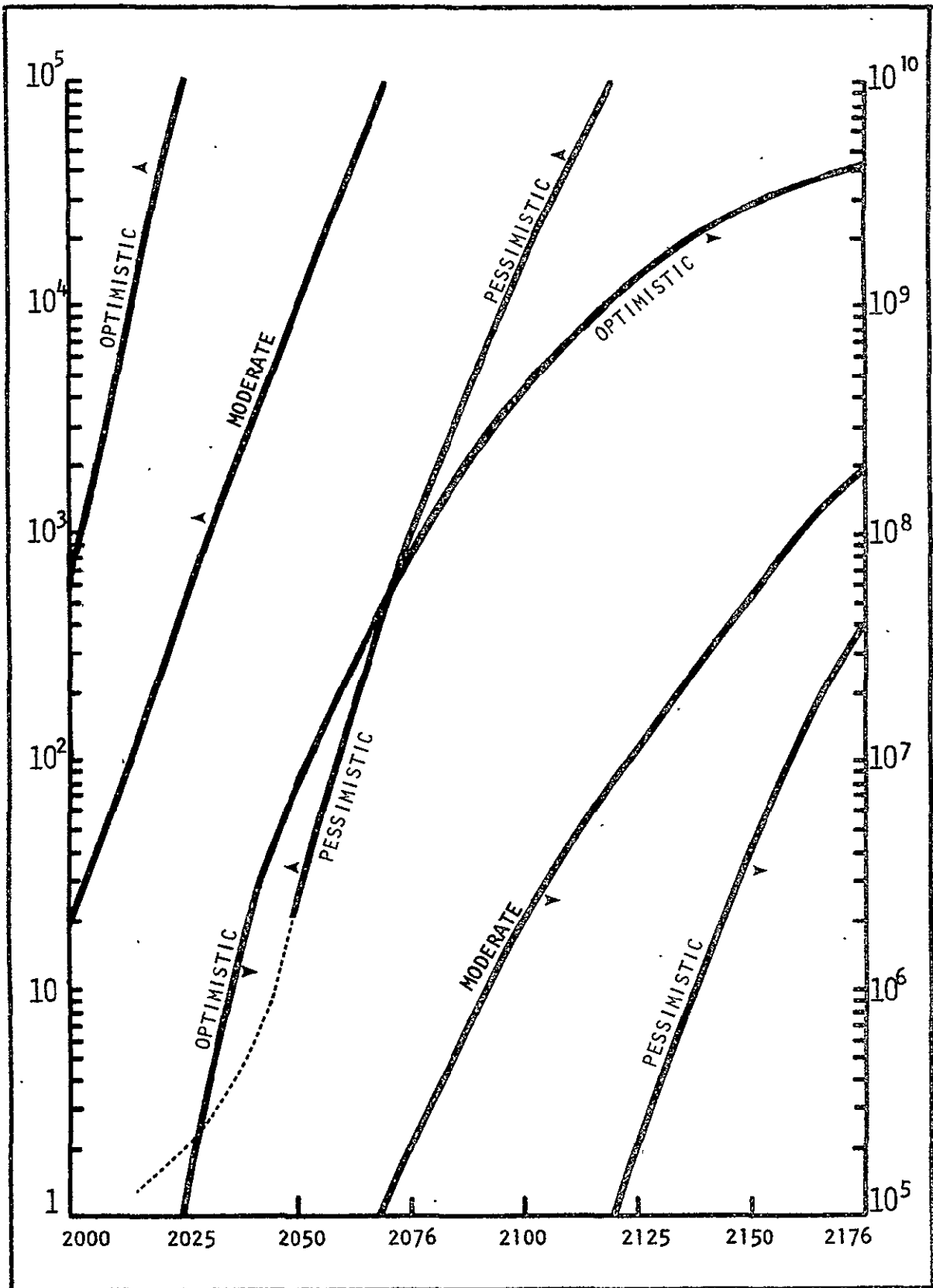
Indeed, the onset of a space tourist industry would increase the utilization of space vehicles and thereby help to reduce the unit transportation costs. Increasing tourism would soon create a need for other space facilities: hotels, hospitals, even convention centers and museums, eventually. As transport costs drop, tours will undoubtedly be extended to visit lunar installations, space industrial facilities, and space colonies. Tours might become a month long rather than a few days--especially while high launch costs tend to preclude repeat visits.

Over time the expected number of space tourists is strongly scenario dependent. We offer some projections in Figure 8 that may be orienting--not because they are "correct" but because they indicate the vast differences that are possible as we move from an optimistic to a pessimistic future from a space development point of view. The great spread between these projections are related mainly to two factors: the average per capita income and the projected launch costs in dollars per pound. In the Pessimistic Scenario about .1 percent of the world's population annually would tour outer space, even after 200 years. In the Optimistic Scenario almost anyone who wants to tour can do so after about 150 years and more than 10 percent do so, annually. Indeed, after 2100, the many purposes of space travelers makes the term, tour, inappropriate in the latter case.

2-2

Figure 8

SPACE TOURISTS/YEAR



Perhaps the most critical of the "Keys" in Table 12 is that related to the health of human beings spending long periods of time in space; particularly for people who would live "permanently" in space colonies and, of course, for those born in space. Currently, so little is understood about potential health problems and solutions to them that we cannot confidently project whether living in space will, on balance, be beneficial or deleterious to a person's health. Even if the effect is small, the difference between a net health benefit and a net health deficit can be enormous to any program in which people occupy space installations. If the net benefits are positive there would be no limit to the numbers of people who might over time prefer to live in space. If the net effect upon health is negative, then, except possibly for a few eager space buffs, working or living in space will require a sacrifice. This should entitle a person to some extra compensation but even so it is unlikely to be attractive on a large scale--at least once the novelty of living in space has worn off.

The health aspects of living in space will have physical, mental and emotional components. The measurement of the total of these effects may, in fact, become very difficult. Suppose the body tends to become physically weaker and of different proportions but the mental capacities improve and the emotional reactions vary depending upon local space cultures and individual proclivities. How do these get added to a net positive or negative result? Also, longevity might be different in space. However, it is not unlikely that by the time substantial numbers of people are living in space--perhaps after 2025--that the average life expectancy on earth might by then have increased to 100 years, or more. In that case

longevity in space might not become established until the 22nd century, except possibly for the results of animal experiments--which might not be convincing.

During the next 50 years the life sciences are expected to experience a radical transformation, as they are in a state of "exploding" progress currently. Certainly, after that much time, much more accurate statements could be made about a person's state of health and of the effect of space travel or space living upon this state and upon the aging process. Whenever such assessments can reliably be made they could prove crucial to space developments requiring the long-term presence of many people. Our more optimistic projections specifically assume at least small net health and/or longevity benefits; in the more pessimistic projections the health effects are at best uncertain.

The fourth key to space development is related to the driving forces on earth. These are on three levels. First, commercial space activities must be profitable. Whether financed by private investors, quasi-public institutions, or governments, they will have to become profitable if they are to receive the infusions of capital required for continual growth. For prolonged rapid growth the required capital flow can become enormous; as can the annual value of space production. The potential growing disparity of these results for three scenarios is illustrated by the projections of Table 13.

These are mind boggling numbers, especially those of the Optimistic Scenario. But even the end result of the Pessimistic Scenario might leave today's space agencies at a loss for projects on which to spend such funds. Moreover, because of technological advances an investment should buy

Table 13

PROJECTED ANNUAL INVESTMENTS AND
PRODUCTION IN SPACE

(\$ TRILLION)

		2000	2025	2050	2076	2100	2125	2150	2176
#1 PESSIMISTIC SCENARIO	B	.015	.045	.075	.14	.20	.30	.4	.5
	P	-	-	.003	.01	.03	.10	.3	.5
	T	.015	.045	.078	.15	.23	.40	.7	1.0
#2 MODERATE SCENARIO	B	.03	.11	.35	0.7	1.2	2	2.8	3
	P	-	.01	.05	0.2	.4	1	2.8	6
	T	.03	.12	.40	0.9	1.6	3	5.6	9
#3 OPTIMISTIC SCENARIO	B	.10	1.0	5	20	50	90	200	500
	P	.02	.4	4	30	180	900	3,600	12,000
	T	.12	1.4	9	50	230	990	3,800	12,500

B = BUDGETS AND PRIVATE INVESTMENT

P = ANNUAL ECONOMIC PRODUCTION, IN SPACE

T = TOTAL, (B + P)

... much more after 200 years than today. Transportation costs alone are projected to decrease by about a factor of 30 even in the pessimistic case.

The second driving force is national enthusiasm. Whether or not the profitable commercialization of space is rapid, many aspects of space exploration and development are known to be extremely important for basic sciences. In addition, we can anticipate many valuable spinoffs from the technological developments, as well as new services to society. National pride in these accomplishments will be a significant factor. It probably accounts for much of the current wave of interest in science fiction that in the U.S. is being expressed through books, movies, and television. A growing national interest and pride in space accomplishments will be required if the public funding of these activities is to increase over time in real terms. Prolonged national enthusiasm appears to be a prerequisite for an optimistic outcome.

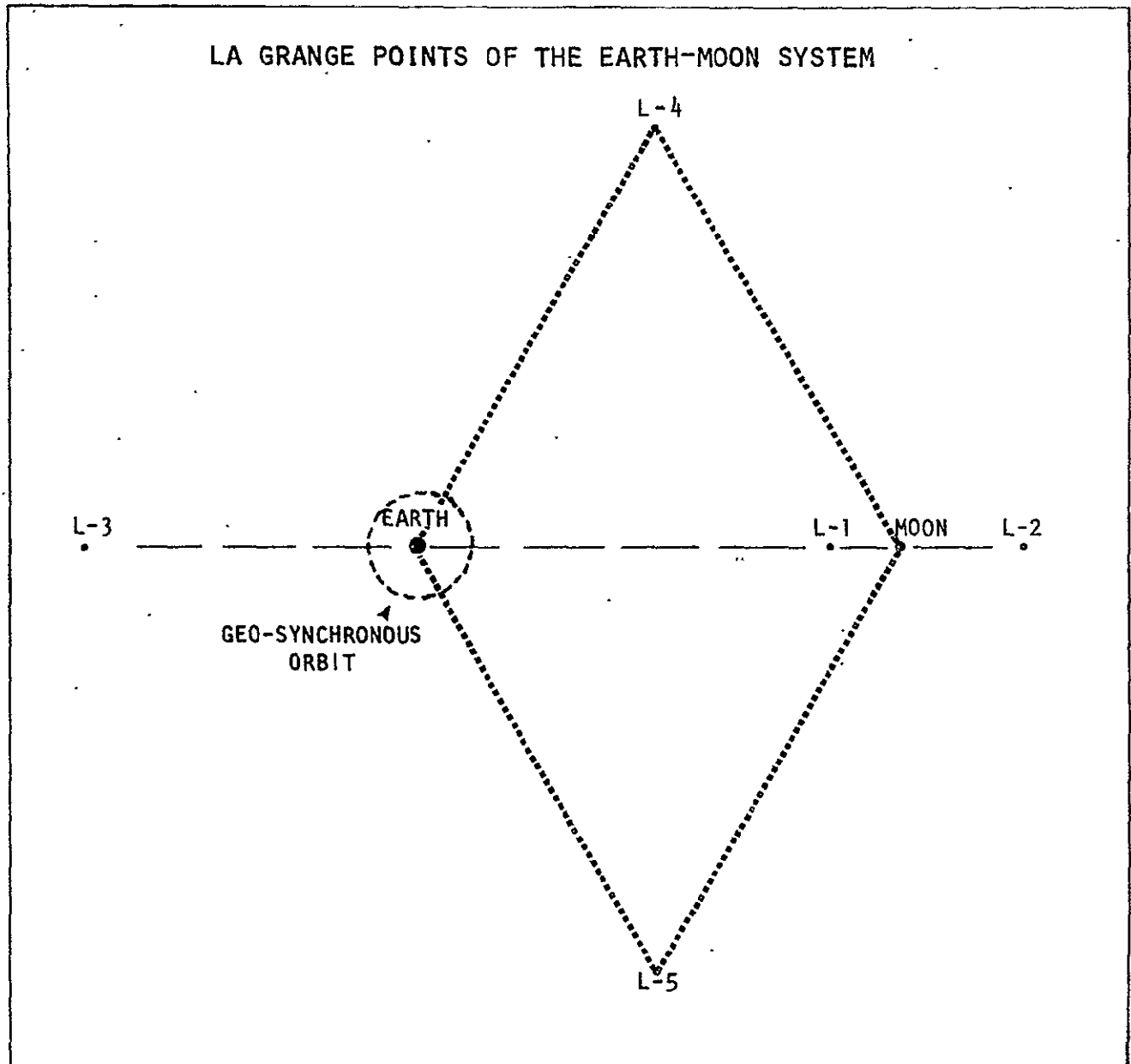
Finally, and potentially of great importance over the long term, is a requirement for international cooperation. Space development will be very expensive, at least for several decades. Without cooperation each interested nation would have to fall back on its own resources, a path which would effectively prevent most of them from participating and which might greatly impede those which do. Competition is often desirable in many enterprises on earth. Cooperation often tends toward a stagnating bureaucratic monopoly. However, for space development such an outcome appears unlikely for at least many decades. The value of a cooperative effort is currently being demonstrated by the existence of the ESA (European Space Agency) and by its joint venture with NASA in the Spacelab

program. Moreover, without such cooperation the persistence of competition, growing competition, could lead to unduly great difficulties in resolving potential conflicts of interest in many extraterrestrial regions.

Eventually unresolved questions of who owns or has prior rights to certain preferred regions of space may become a constant irritant to international relations. All of the preferred regions of space are not yet known, but we can guess at a few. For example, at least four of the five La Grange points are of potentially very special importance because these are the only stable space points in cis-lunar space (stable with respect to the earth-moon axis--see Figure 9). The four points are L_1 , L_2 , L_4 , and L_5 (L_3 is omitted only because we are unaware that someone has yet conceived of a special use for it). Other special points or regions would be the poles of the moon where nearly perpetual sunlight might be available and where water is most likely to be found in nearby craters; and the moon's "equator" (the line around the moon's surface which lies in the plane of the moon's orbit about the earth). This "equator" should be the most valuable for launches into cis-lunar space--especially for launching of lunar materials, destined for any of the La Grange points, with an electromagnetic accelerator constructed on the moon's surface. Even the earth's large but unique Geosynchronous Orbit, a circle with about a 160,000 mile circumference, might in time become crowded. Can segments of this circle be claimed for national rights?

Perhaps of even greater importance would be the need to feel that over the long term space installations and satellites would be safe from military threats. Orbiting manned space stations crossing over enemy

Figure 9



territory during periods of overt hostility might become particularly stressful places to be "trapped" in--especially if any deliberate damage to space satellites had already occurred. While space warfare might be preferable to terrestrial warfare, it can hardly but create an atmosphere restrictive to peaceful developments in space--especially, manned space installations.

One specific area in which international cooperation or space law may become very important is related to space debris. The tendency to assume that space outside the earth's envelope is so large that man-made debris may be ignored has certain limits. Natural processes will always provide regular cleaning services to some extent. For example, gaseous emissions are swept away by the solar wind when not otherwise captured by atmospheric envelopes. Objects orbiting within 250 miles of the earth's surface generally will be captured in less than a decade, or perhaps much less, the time depending on the geometry of the orbits and the sizes and shapes of the objects. Perhaps the most dangerous kinds of debris are those of small but greater than microscopic size--e.g., orbiting remnants of explosive bolts or small bits of debris produced by random collisions among uncollected orbiting objects. These bits of millimeter- or centimeter-sized objects might accumulate to dangerous proportions in long-lived orbits if their formation is not effectively prohibited by appropriate space law. The contemplated future transport of raw materials from the lunar surface to various earth orbits must be accomplished without "leakage" especially if, as has been visualized by O'Neill and others, the raw materials are to be catapulted into space

and subsequently collected.* It is not too early to attempt to visualize all the kinds of space debris which might become dangerous and to devise ways to ameliorate the potential threat. Certainly the principle of keeping space--especially cis-lunar space--safe from collision with man-made debris must soon become an essential part of space ethics.

Thus, although it appears that international cooperation in developing space would be rewarding for all concerned, history alone would suggest that such cooperation is at best temporary. But history itself is an unreliable guide to the degree of future international cooperation or its effect upon the outcome of space developments. However, history has shown that competing nations are often willing to make great sacrifices. Then, and often only then, are the pressures great enough to cut red tape, to accelerate their programs, and to take the risks required to prevail. Cooperative ventures, on the other hand, usually need to achieve a continuing consensus, sometimes there is a reluctance to spend more than (or even as much as) the original commitment, and much haggling may occur over proper sharing--especially if there is an overrun or change of plan. Furthermore, no single nation may get great credit for a successful outcome and the psychological potential for exhilaration tends to be diminished.

The above characterization is often but not always true. Cooperation can cause high morale when it creates something important that most people approve of. One can imagine for example a very large multinational effort to build a cooperative lunar facility that is enthusiastically supported by the participants, even while some of the subsidiary

* Gerard K. O'Neill, The High Frontier: Human Colonies in Space (New York: William Morrow and Company, Inc., 1977).

component efforts remain competitive. A cooperative lunar effort could also exist during any ongoing competition for leadership in earth-orbiting space facilities. Thus, future space programs might achieve many of the advantages of both cooperation and competition. Of course, the particularly useful cooperative projects would be those which might not otherwise be feasible.

It might also turn out that cooperation in large space projects helps to resolve some conflicts on earth, perhaps because it refocuses attention on new important areas; but to expect this outcome may be wishful thinking. In the Moderate Scenario discussed later (Chapter VI) we describe a lunar venture which starts cooperatively and then, after the cooperative context is severely eroded, finds that unexpected benefits ensue.

It is also important to distinguish between minimal passive cooperation and high levels of active cooperation. A tacit agreement to avoid violence in space is a minimum level of passive cooperation which should be relatively easy to achieve. Investing huge sums in a joint lunar space station would be a high level of active cooperation.

Hostile competition or even war can sometimes be conducive to space developments. Certainly, this has been true in the past (e.g., ballistic missiles, anti-missiles, reconnaissance satellites,...). In the future one can at least imagine, for example, a protracted war totally restricted to battles in space. In this circumstance if both (or all) sides are making "all-out" efforts to win, they would need to be accompanied by mobilizations to acquire the maximum capability for exploiting the militarily useful resources of space. By way of analogy, much historical

exploration and development has been motivated by the search for military bases abroad and their associated strategic considerations. Thus it seems possible that space development might, paradoxically, be the recipient of future benefits from either excellent cooperation or vigorous competition.

The last of the "keys" appears to be the most difficult to analyze. It is related to assumed evolving and growing space cultures--people organized into "societies" living in space. Initially, such societies may have fewer than 10 people, and eventually grow to 100,000 or more. The social and psychological effects of prolonged living in space in any of a variety of habitats, none of which is presently well understood even in physical terms, will have to be discovered through experience. It is not at all clear that there are special preparations nor a selection process that can be devised on earth which could assure the viability of such social systems in space. If the societies grow very large then they are likely to develop internal political systems whose nature could be completely foreign to our past experiences.

We now find only great uncertainty in the conjectures about the processes of making psychological, social, or political adjustments. Whether learning can effectively be transferred from one troubled society to another or to its successor in order to improve its prospects--or indeed whether any troubled societies in space will actually emerge in any important sense--appears to be almost completely a matter of conjecture.

A "solution" contemplated by O'Neill for large space colonies to be located near the L-5 La Grange point is to construct them so that they appear and feel almost identical with the earth environment--at least during a normal social mode--complete with wind, rivers, clouds, trees,

animals, plants, houses, and with the earth's gravity.* Whether this would be desirable or even feasible cannot be known for sure. It is an interesting and "conservative," if expensive, concept which like any other would have to endure thorough subsequent reality testing.

Any "solution," of course, would also have to be sustained through a period of assumed rapid growth. If these societies are economically viable then over time they would be expected to increase in size and number, perhaps very rapidly. Based upon our past experiences this process alone can be expected to bring additional socio-political challenges, the satisfactory resolution of which would have to evolve relatively peacefully.

The societal problems presented here appear to be quite beyond our primitive analytical powers. We will assume that acceptable solutions or resolutions are possible, postulating lesser or greater degrees of difficulty according to rather arbitrary standards. Naturally, in the most optimistic scenario any such problems will be overcome with the least difficulty.

This chapter, which is largely devoted to the future of technology with an emphasis on space, might appear to some critics as an indulgence in "mindless" technological optimism. We would take strong issue with any such accusation since we find little to support arguments that the contemplated developments cannot occur, although our judgments about timing might be in error--in either direction. This is not an argument

*O'Neill, The High Frontier.

about the degree to which the results or consequences of such new technology will be good or bad, on balance. That involves value or philosophical issues or judgments which are generally outside the scope of this study. Rather, for those interested in space futures we are attempting to make a persuasive case which will develop a sense of technology's potential for changing economic standards, qualities of life, and resolving important issues. Most of the future technologies that we have described appear to be solidly "in the cards" that are yet to be dealt. Indeed, some very interesting "wild cards" are possible--or even very likely--that cannot now be imagined.

For those who have been relatively pessimistic regarding long-term technological prospects, our portrayal might help to reduce such pessimism and restore some confidence in the future. Still, we have also looked at the pessimistic side and found many approaching potential problems for future societies, especially technological problems which relatively careless societies might have to cope with. Readers interested in our views in this area are referred to Chapter VIII of The Next 200 Years, entitled "From Present to Future: The Problems of Transition to a Post-industrial Society."

~~PRECEDING~~ PAGE BLANK NOT FILMED

Chapter IV

OPTIMISTIC SCENARIO

PART I: THE TRIUMPH OF THE MACHINE? (1976-2000)

A. The Explosion of Technology

Although it was not easy for national leaders in the developed countries to realize it during the 1970s, in part because of the economic shocks (inflation, energy crisis, unemployment, material shortages, food shortages, etc.), individual technologists were becoming aware of the very rapidly growing analytical and industrial power in their fields--although they may not have been too aware of the parallel growing power in other areas of science and technology.

The last to understand the new phenomenon was the New Class. Its influence in the developed countries had peaked in the late '70s and subsequently faded out over the next decade. By 1990 only scattered remnants of its ideology remained influential. The major reason for the decline was the growing general awareness that, contrary to previous conclusions, competent management coupled with innovative technology could provide economic growth and a generally improving quality of life--as measured by health, safety and environmental purity.

The futurologists soon became aware of the knowledge explosion which they believed "started" in the '60s (actually it was the '50s) and which became a popular intellectual term in the decade of the '70s. But then, because of the natural lag between new knowledge and its application, the real tide of innovative technology (except for microcomputers which became popular in the mid-'70s) was not to become widely observed until the '80s--and the crescendo swelled from then on.

The technological ground swell was greatly aided by magnificent inventions and developments in basic sciences, electronics, communications, lasers, space exploration, and a growing array of powerful new scientific instruments. Nearly all of the rapid progress in technology, in one way or another, usually quite directly and impressively, was related to the solid state electronic computer. In the amazing sequence of computer development each new computer was itself assisted by the previous generation of computers in a scientific marvel of "bootstrapping."

B. The Early Space Program in the U.S.

The development of the U.S. space program after the brilliant Apollo moon landings (which, were it not for the exceptional progress in computers during the early 1960s, could easily have resulted in disaster and aborted the space effort) nevertheless sank to its lowest funding level just as the first Space Shuttle became operational in 1980. In that year NASA's budget (in \$1975) sank to \$2.9 billion, its lowest level since the lunar landing. The government's (that is, the public's) inability to appreciate the future potential of the space program had led it to adopt a wait and see attitude--while Congress allowed the inflation of the 1970s to further erode NASA's real buying power--until the visible space benefits became so overwhelmingly clear that it was impossible for the public to continue to ignore it. The early budget history of the U.S. is given in Table 14.

Although this wrinkle in U.S. space program history was to be subsequently regretted, in the sense of opportunities lost through short-sighted delays, it also set up a psychological basis from which nearly exponential growth was to occur for a very long time to come.

Table 14
FEDERAL BUDGET 1961-1977

FISCAL YEAR	TOTAL FEDERAL BUDGET*	NASA APPRO- PRIATION*	NASA APPROPRIATION (ACTUAL \$)
1961	\$201,437	\$1,758	\$ 964
1962	212,814	3,269	1,825
1963	183,380	6,485	3,674
1964	230,511	8,863	5,100
1965	235,691	8,927	5,250
1966	268,566	8,520	5,175
1967	291,959	7,945	4,968
1968	291,780	7,023	4,589
1969	285,874	5,822	3,995
1970	294,568	5,185	3,749
1971	311,142	4,359	3,312
1972	313,531	4,183	3,310
1973	329,775	4,066	3,408
1974	341,339	3,306	3,040
1975	412,099	3,231	3,231
1976 (ESTIMATE)	385,105	3,353	3,555
1977 (ESTIMATE)	388,429	3,313	3,697

* IN MILLIONS OF CONSTANT 1975 DOLLARS.

The technological heart of any space project, naturally, was the electronic computer. NASA in its OFS study had stated quite clearly:

Without the speed and accuracy of automated data handling the space ventures...would be neither practical nor possible. Use of the computer now pervades all NASA activities, so much so that it is surprising that its necessity was not foreseen

in most of the science fiction written about lunar and planetary exploration before it actually began.*

With this recognition, and with the near certainty of continuing rapid increases in the power of computers and instruments, NASA recognized that applied scientific progress was "exploding" (see Tables 7 and 8, Chapter III). Indeed, those who looked carefully also saw that the power of basic theoretical science was also to be developing with continuously increasing rapidity. An immense (and rapidly growing) problem-solving capability with a competence that was not previously suspected except by a few avant-garde technophiles was being made possible by the improved sciences, the new instruments, and the leverage provided by the amazing computer. With these forces working in cooperation a new set of closely integrated technological marvels was to be witnessed by the world--some of the greatest of which were to be in the developments in space--in its science, exploration, earth applications, travel and industrialization.

C. The Earth-Centered Context

As the stage was being set for the burst into space after the turn of the century there were a number of interesting developments "on the ground" that, coupled with space information systems, were to be "arranging the chairs." We will mention a few of these here for orientation.

1. Energy Supplies

The conventional wisdom (i.e., the myth) of the early 1970s that the world was running short of energy--usable, relatively inexpensive

* National Aeronautics and Space Administration, A Forecast of Space Technology, 1980-2000, SP-387 (Washington, D.C.: Scientific and Technical Information Office, January 1976), p. 3-3.

energy--which so frightened the nations of the developed world at the time (and gave such megalomaniacal fantasies to the OPEC countries) had disappeared by 1984. It wasn't even that energy self-sufficiency had been achieved anywhere. Rather, it was by then clearly apparent, even by former believers in the limits-to-growth philosophy, that such immense reservoirs of energy were about to become available in natural gas, in coal, in shale, in uranium and thorium; in geothermal and solar sources; (and even in conventional petroleum sources--the location and extraction of which had undergone a major revolution in a mere decade); in conservation by more efficient conversion to electric power, by utilization of formerly wasted heat, and by new designs for efficient utilization of energy; that most of the newly rich OPEC countries deeply committed to industrial development programs found themselves with unforeseen worries. Their market clearly would slip rapidly away unless the price of oil was reduced by about 1/3 to about \$10 per barrel, delivered in the U.S. The decade 1985 to 1995 saw the development of inexpensive reliable solar cells and a myriad of ways of adapting them to autos, trucks, homes, buildings, factories, farms and central power stations--in addition to the obvious implication for their potential use in space transportation systems or for their application to space-based electric generators which could even supply power to the earth, if necessary.

Also, the anti-nuclear-power movements of the '70s had diminished considerably by 1985 as the ability to control the nuclear fuel cycle had become well understood technically and communicated to the public. New designs promised with some confidence a steady improvement in the efficiency and safety of fission reactors. Indeed, it was recognized

that economics alone would demand this--else the fission reactor would be displaced by the improving cost-effectiveness of its competitors. (Also, by the late '80s the gaseous-core nuclear reactor had become the potential future champion in nuclear-fission engines for space transport that promised to be hard to beat. Still there was the coming competition from nuclear fusion engines to "worry about.")

Even though the economics of fusion power for earth-based systems was still in doubt great strides in the technology of fusion systems "popped up" every year--seemingly out of nowhere, if one's information came only from news media sources--and the prospects were exciting not only for inexpensive inexhaustible fusion power after 2005, but for highly efficient fusion-powered engines for space transportation by 2010.

Also geothermal energy, the "orphan" of the energy prospects in the early '70s, had not only "surprised" the world by capturing a large share of the commercial electric power market so rapidly but the development of the geothermal zones of the Gulf Coast furnished copious quantities of natural gas in addition to the electric power.* Moreover, it became expected that this resource, worldwide, would develop a 200-year reserve of natural gas. Although the initial production of this gas was only barely competitive, the improvements after the turn of the century were to reduce its production costs by more than half.

These developments were somewhat depressing to commercial interests which had large investments in the solid fossil fuels. Although the

*William M. Brown, "100,000 Quads of Natural Gas?," HI-2451/3-P (Croton-on-Hudson, N.Y.: Hudson Institute, October 1976).

technologies associated with these energy sources had made good progress--especially in-situ conversion processes--their competitive prospects were dimming by the year 2000. Still these technologies and the solid fossil fuels would be available for as long as they were needed to facilitate the transition to the cleaner abundant energy supplies.

2. Resources

To a surprising extent the worried world of the early '70s had come to think of natural material resources--especially the metals--as finite and exhaustible, as if they were soon to be dispersed in the sea or thinly scattered over the land within uncollectable buried trash. By 1985, despite a booming world economy, such images had disappeared except as amusing anecdotes. In a mere 15 years technologically oriented efforts had:

- (1) doubled the estimated recoverable resources of most formerly sensitive metals such as copper, lead, mercury and silver;
- (2) started mining the nodules of the sea in commercial quantities;
- (3) developed "inexhaustible" alternatives for the major uses of copper, silver, mercury, chromium, lead, zinc, and tungsten--at least for most of their commercial uses in that year;
- (4) developed and demonstrated recycling systems that were soon to be at least 99 percent effective for recovering the valuable metals from liquid wastes;
- (5) reduced the relative amount of metals required in industry by creating more efficient designs and steadily increasing the use of new plastics, ceramics, glasses, and composites as substitutes;
- (6) found several new methods for extracting metallic minerals from sea water, more than one of which seemed almost certain to become economic early in the 21st century; and
- (7) probed the lunar surface and a few of the asteroids with extraordinarily promising results for the 21st century and beyond, when minerals from these sources would be useful for a burgeoning space industry.

3. Environment

Every major developing country made very substantial progress in improving air and water quality during the '75-'90 period and moreover in many cases had developed ways of changing pollutants into assets. For example:

- (1) Solid wastes were turned into foods, fuels, fertilizers, and mineral sources.
- (2) SO₂ pollutants became a major source of commercial sulfur or sulfuric acid.
- (3) Coal ash increasingly was used for road surfacing, concrete blocks, fertilizer, a source of minerals, and desirable land-fill projects.
- (4) Nuclear "wastes" were increasingly providing valuable isotopes for industries and medical research; processes to recover and return 99.99 percent of plutonium and other actinides to the fuel cycle were developed and successfully tested.
- (5) Programs for the utilization of most of the formerly wasted heat from power stations and manufacturing plants were steadily reducing energy wastes.
- (6) The recovery of low-level metallic wastes down to 1 ppm was to become routine in all the important industries.
- (7) Biological "pesticides" were replacing chemical ones at an increasing rate.

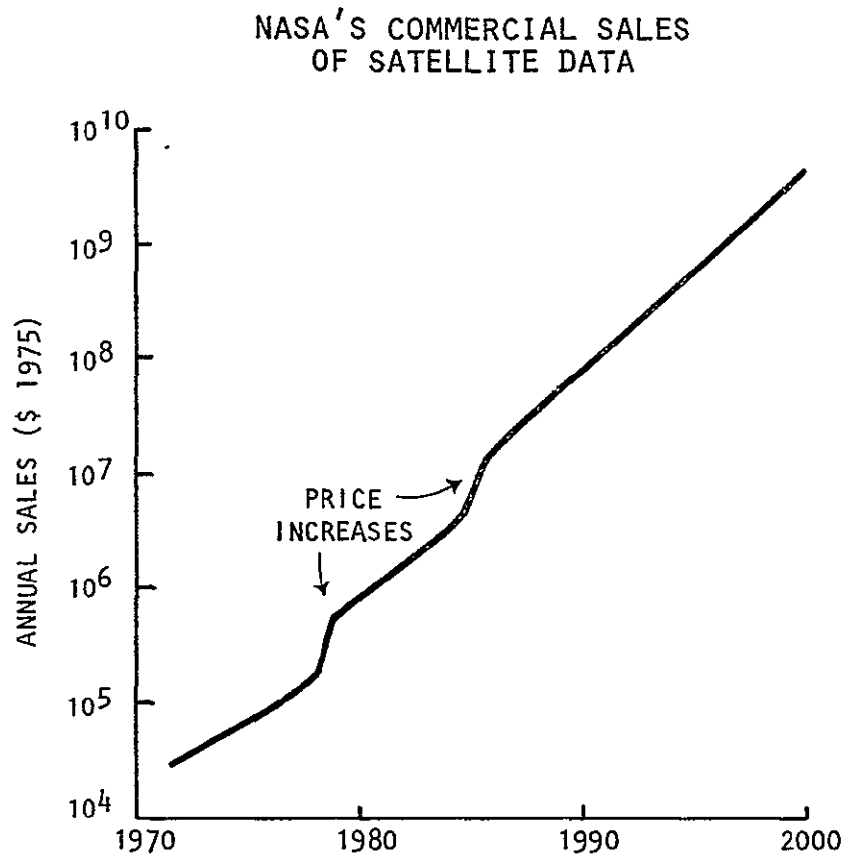
By 1985 the potential utility of most of these processes had only just been developed and their future utility was generally (and rightly) believed to be even brighter. In the decade before 1985 many people had considered the space program as a way to get rid of nuclear wastes; that is, using space as an unlimited trash receptacle. Although this solution was possible, others on earth were soon found to be much more feasible.

4. Food

Although the medium-term (2000-2025) prospects for adequate food supplies were generally perceived to be very bright, the shorter term needs before the year 2000 were to remain marginal or dangerous for a few of the less developed countries with massive populations that were dependent upon good weather and/or the good will of the food exporting countries. Although their position was not secure it was to improve more or less steadily after the early '70s. Moreover, it was realized by most people in the world that, basically, the most important requirements for agricultural progress in the poorest countries were adequate incentives for the farmer and protection from a crippling bureaucracy and its regulations. Effective agricultural and economic assistance was to become readily available for needy regions where more and more governments helped rather than hindered the flow and utilization of such assistance. As early as 1985 there were at least 30 models of developing countries that had been responsive to the emerging ethic--that aid was available to all who would accept and employ it effectively.

Space-based systems played a growing role in nearly all of the above developments. This role was interesting, if somewhat obscure, during the '70s; but by the early '80s these systems were offering such valuable information to those institutions that were learning to utilize it that the number of customers for NASA's programs increased at a phenomenal rate. The U.S. government soon realized that an interesting source of revenue was at hand and, as a result, the receipts from sales of information from satellite systems grew rapidly--as is shown by Figure 10 for

Figure 10



the period 1970-2000. This income together with a growing demand for Space Shuttle services in the '80s led to the growing NASA budgets after 1982. By that time it had become quite clear that NASA's information from earth applications satellites was a great bargain and could be sold at substantially higher prices, where that was a desirable course for the U.S. government.

D. Improved Space Vehicles

1. For Launch to Near-Earth Orbit (NEO)

Designs for advanced launch vehicles which could greatly reduce transport costs had been sketched since the early '60s and many of the promising alternatives were discussed in the 1975 OFS study. However, budget constraints forced NASA to postpone any serious large-scale effort until 1983. Nevertheless, enough of a useful technological base existed, thanks in part to the efficient use of computer-aided designs, that when the upturn in the budget occurred in the early '80s NASA was quick to respond with projects for two major vehicles:

(1) The second-generation completely automated shuttle which became operational in 1989 and reduced transport costs by about a factor of 2 (initially to about \$150 per pound and later in that decade--after further improvements--\$100 per pound). It became the first vehicle to take tourists to space on a commercial basis.

(2) The 1/2-million-pound payload SSTO HLLV which became operational in 1996 and was soon delivering non-human payloads to space at \$18 per pound and which (by 2005) was sending materials into space at the rate of 2 billion pounds annually. (About half were U.S. payloads up to this point

in time, but this fraction was to be gradually reduced as the space capabilities of other countries were increasing rapidly.) Indeed several countries (Japan, England, France, and Germany) had placed orders for one or more of these vehicles and would take delivery by 2010.

During the late '90s radical designs were being worked on for new SSTO vehicles which were again to reduce launch costs (to \$8 per pound by 2025), in part because of the availability of metallic hydrogen as a fuel. The economics of space transportation in terms of the cost for launching inanimate objects into NEO for the 1976-2076 period--and the current projections to 2176--appear in Figure 3 (page 81). It must be remembered that the costs for human transportation, which because of the G-restrictions and other required amenities, were to remain greater than average "freight" costs by factors ranging between 2 and 4.

2. Propulsion Systems for Orbital Transfer Vehicles

Before the Space Shuttle became fully operational in 1980, the first vehicle considered for transporting satellites from NEO to more distant orbits was the Interim Upper Stage, a relatively inefficient system whose chief virtues were its reliability, its low cost to develop and manufacture, and its availability when the Shuttle became ready for routine use. However, the costs in using this transfer vehicle were relatively high; since it used solid propellants it was an inherently heavy and non-reusable system. Therefore, before the Shuttle became operational NASA contractors had developed a modified orbital transfer vehicle, the Spinning Solid Upper Stage. This non-reusable vehicle was still encumbered with solid propellants but was considerably more efficient for many purposes. These

two vehicles clearly constituted a stopgap arrangement for orbital transfers, mandated by the tight budgets of the '70s.

To complete the Space Transportation System (STS) many concepts and preliminary designs for the required new orbital transfer vehicles existed. These advanced "space tugs" only needed the caress of new funding to enter into serious competition for the future STS. They started to pour out of the design boards during the early '80s and by the end of the century an imposing array of new alternatives from the Solar Sail to the Fusion Engine were available or in development (see Table 15).

E. Space Industrialization

Prior to the Space Shuttle era one of the more difficult concepts for the public to accept as a coming reality was that of "floating factories" in space. Naturally, the earth-centered mind had difficulty envisioning a steel mill or copper smelter in orbit. This is quite understandable--particularly if one had visited any such installation on earth. However, the MISS (Made In a Space Station) concept had penetrated the minds of space technologists frequently enough that by 1980 the detailed plans for early ventures in space manufacturing and construction were well along and indeed some preliminary notions had been tested, in principle, during the earlier space flights of the '70s.

Still, after the first successful Shuttle-based experiments were reported by the news media in 1980, it took a few years for the public to begin to adjust to the approaching reality--that space could become increasingly and relatively rapidly industrialized--even though an orbiting steel mill was not a likely prospect for a 20th-century venture.

Table 15

SPACE TUGS IN OPERATION OR IN
DEVELOPMENT BEFORE 2000

<u>PROPULSION CONCEPT*</u>	<u>YEAR DEMONSTRATED</u>
1. IUS AND SSUS (SOLID PROPELLANT)	1980
2. SOLAR SAIL	1982
3. CHEMICAL ($F_2-N_2H_4$)	1983
4. ION ENGINE (Hg)	1985
5. CHEMICAL (F_2-H_2)	1986
6. COLLOID THRUSTERS	1987
7. E-M ACCELERATOR (MPD)	1988
8. BEAMED ENERGY	1991
9. NUCLEAR FISSION	1992
10. ADVANCED METASTABLE CHEMICALS	1996
11. ADVANCED NUCLEAR FISSION	1997
12. NUCLEAR FUSION (1st GENERATION)	2000

* IUS: INTERIM UPPER STAGE
 SSUS: SPINNING SOLID UPPER STAGE
 E-M: ELECTRO-MAGNETIC
 MPD: MAGNETOPLASMODYNAMIC
 CHEMICAL SYMBOLS--Hg: MERCURY
 F: FLUORINE
 N: NITROGEN
 H: HYDROGEN

Perhaps the completion and operation of the first space station in 1983, followed by the construction of the 100-meter-diameter antenna in 1984-- both highly publicized and well-photographed events--were among the more significant experiences which affected the public's space imagery. Through television they were able to become "sidewalk superintendents" of these milestone events and were thereby easily able to bridge a gap which otherwise would have required a quantum jump in imagination.

The early prototype MISS products soon became highly valued collectors' items. The first crystals, alloys, whiskers, silicon chips, glasses, castings, and ball bearings from the space laboratories indeed became prized museum pieces. But more important was the spreading knowledge of the special properties and commercial uses of MISS products and processes-- and of the potential for large space structures.

Having witnessed the construction of the first relatively simple installations in the form of modular depots, habitats, R&D laboratories, etc.; the elaboration of the more complex space stations to come could be more readily depicted and accepted. Thus, the psychological stage was set for a flurry of new interest in the development of Space Industrialization (SI). Shortly afterwards, in the '80s, when it became understood that excellent profits might also result from many of these ventures and that the potential for future growth was very large (some claimed "unlimited"), the fancy of many investors was ensnared and the first boom in Space Industry stocks was on. Of course, there were some foolish enough to make naive investments, and in those days some unscrupulous commercial promoters existed who preyed upon emotional outbursts of this

type. But the few cases of incompetence or fraud did not seriously detract from the reality of the impending developments. The first major commercial SI facility was completed in 1991. It was nearly completely automated, yet about 60 people had to live in space just to operate and maintain the facility. Its first products were biological materials of great purity unavailable from earth-bound processes (vaccines, hormones, enzymes) and processed silicon "chips" for computers. This facility was followed only five years later by one more than 10 times as large, operated by about 150 people. Soon after that production in space as a concept was to become routinely accepted. A "steel mill" in space was expected to be only a matter of time--at least it could no longer be a startling surprise. The space technologists, of course, were thinking more about high-technology processes involving computers, lasers, robots, space vehicles, colonies and lunar supplies.

F. Lunar Program

By the early '90s there were enough space tugs available to establish and supply a manned lunar base. The first arrivals (from a joint U.S. and U.S.S.R. project) landed on the moon in 1992 to set up a permanent station for scientific and exploratory purposes. Two colonies were set up, one on the far side of the moon to permit optimum astronomical observations, the other on the near side for a general research laboratory and exploration center. By the end of 1993 twenty people were living on the moon and supplies were being delivered regularly for developing their underground habitats and their surface operations. These first colonists (15 men, 5 women) were an extremely capable group which, within a year,

had found sources of water on the moon that in some places could be reached by wells less than 500 feet deep. This discovery made it certain that the moon would soon become an extremely important link in future space programs.

In principle, the moon could soon provide essentially all the material needs of its inhabitants and become a relatively inexpensive source of materials for space structures and of propulsion fluids for space vehicles. By the end of the century there were 275 colonists and the observatory was in its 4th year of operation. During the next quarter, the industrial program for developing lunar resources was to make possible the construction of the first large colony in space at the L-5 "point."

A major goal of the 20th-century lunar colonists was to establish the feasibility of using the moon for many purposes other than scientific observations. Although the anticipated scientific rewards related to astronomy, geology, and astrophysics alone were believed to be sufficient to make the venture worthwhile, the huge long-term payoff depended upon the successful solution to a number of problems such as (1) finding water; establishing a "nearly" closed-cycle ecology; demonstrating the feasibility of living comfortably for years at 1/6-G and returning to earth without deleterious health problems; establish the feasibility of mineral exploration and mining; and successfully resolving the sociological problems which tend to arise in any new environment, but which could be especially severe when the change is as sudden and as encompassing as that posed by the airless "barren" moon where each lunar day is 14 times longer than an earth day.

If the satisfactory resolution of these problems could be achieved then the feasibility of colonizing not only the moon but the "whole solar system" might be established, in principle. That this lunar feat was essentially accomplished by the year 2000, less than 50 years from the time that the first small earth satellite was launched, provides a stunning perspective on the great technological transition that characterized the second half of the 20th century. (During that time, paradoxically, many citizens, and even some national institutions, were actually demanding a return to a simpler way of life on the grounds that there would be insufficient energy and materials available at reasonable costs to support for long the ordinary earth-centered activities of human civilization.)

G. First Tourists

After the second-generation Shuttle became operational in 1989 (officially the last year of the Bicentennial celebration), a prior plan was carried out to demonstrate the utility of this vehicle by introducing the public to the concept of commercial space tours. This tour was a very well publicized three-day voyage to near-earth orbit which included a rendezvous with the recently completed international Space Station, within which the "tourists" were accommodated. The passengers for this voyage were NASA's director, the governor of Texas, 2 Senators, 6 Congressmen, the French ambassador and 12 other VIPs, together with Marlon Scott and Elizabeth Welsh, the best-known movie actor and actress in the U.S.

The special two-hour videotape documentary of the event became a tremendously popular worldwide success--in large part because the enthusiasm emanating from the famous actors was vividly conveyed by their

spontaneous behavior during the voyage. In addition their subsequent "orchestrated" television appearances further stimulated public interest in space projects--especially space tours. By means of this single event, for the average citizen the potential of space ventures was transformed away from its prior "fictional aspects" and could be perceived as a growing set of real activities with great commercial promise. Of course, the social utility of the space program, as it became recognized, made it increasingly popular. This utility was achieved mainly through the use of earth-application satellites and advanced COMSATS, but also because of scientific advances made possible by space probes and planetary exploration. For example, Future Space Developments became a subject taught in schools around the world. However, the realization by average citizens that perhaps they, too, or certainly their children, might safely visit outer space--perhaps even stroll on the moon--was crucially important in creating favorable public attitudes. Outer space, more and more, became a real world which anyone might experience, in principle; and for those who had a sufficiently strong desire, the possibility now existed to actually go up there--at least once.

Indeed by the end of the century a new company, International Space Tours, Inc., announced that 1200 people would "tour outer space" that year in the first commercial system licensed for that purpose. The cost that year was to be \$150,000 for a one-week tour confined to near-earth orbit. Still, the demand for seats was at least ten times the capacity of the system--even at that price. It was a good start for a fledgling business, one that was destined to become one of the world's largest.

H. International Cooperation

The Apollo moon landings in large measure had been driven by the need felt by the United States to recover its (Sputnik) shattered image as the world's leader in science and technology. The Americans assumed it was a race and gave it the resources required to win--even though the Soviet Union denied it was entering the contest. The enormous prestige that the Americans gained around the world from the successful program soon after frittered away as the gloomy national malaise of the '70s set in. The flood of socio-political problems during and after the Vietnam involvement turned the public away from "large" space budgets. The conventional wisdom of the '70s claimed that, instead of billions of dollars for "a few moon rocks," the money should be allocated for social purposes. The one-sided space race had indeed ended. As NASA's budget declined and its world-renowned capability eroded during the decade of the '70s, NASA wisely attempted to stretch its resources through promoting cooperation in space ventures with the rest of the developed world, including the U.S.S.R. The cooperation effort was publicly announced but was not trusted by many Americans, who tended to see the Soviets as a potential enemy. But the cooperation became effective, in fact as well as words. Although its beginning was slow the interaction among the various national space agencies was to bloom into an enormously rewarding program for all humanity.

The major milestones of the 20th century were the U.S.-S.U. Apollo-Soyuz linkup of 1975; the 1980 Shuttle launching of the Spacelab module built by the European Space Agency; the first space tour mentioned above; and, perhaps most significant, the international funding in 1988 of the \$50-billion 10-year program for the so-called Super Shuttle STS--

the first fully reusable unmanned SSTO 1/2-million-pound vehicle for launching payloads to near-earth orbit, in addition to a new array of advanced "space tugs" to complement this launch capability. The program grew to \$100 billion as an extension and measure of its success, not because of cost overruns. NASA had the central responsibility and continued its successful management history by keeping within the budget. The design of a second-generation SSTO vehicle that evolved before the end of the century was a modification to incorporate the technology of the new superfuels (which contained a large fraction of mono-atomic hydrogen) and which became feasible in 1995. Shortly after the turn of the century this vehicle tripled the SSTO's payload capability, with the same gross weight at lift off (10 million pounds).

The major benefits from the cooperative international effort included (1) avoidance of duplicated development through technological exchange, (2) earlier funding of huge projects, (3) the establishment of international laws and procedures for settling disputes about "rights" in space and planetary bodies, and (4) perhaps most important, the effective restriction of space to peaceful purposes (of course, observation satellites obviously could be used for military intelligence, but weapons in space were strictly forbidden).

The international cooperation, which skeptics originally predicted would soon decline or collapse for the usual political reasons, developed instead an unexpected aura of the kind that is associated with successful enterprises and resulted in the rapid sharing of information, mutual technical assistance, and a surprising minimum of friction among the dedicated personnel. Indeed, in each participating country an attitude developed

among those associated with the space program that resisted the political pressures to obtain special "advantages." Since projects for the development of space were able to avoid many of the usual national struggles for material advantages or ideological goals, it is not surprising that the space community increasingly became international, or rather, intrasolar in its perspective.

1. The Space Culture

In each nation the natural heroes of those interested in the movement into space were the astronauts. In manned space ventures the work to be done literally became a full-time occupation--roughly a 100-hour week. Quite generally an astronaut's occupation also became his primary recreation. A self-selection process evolved that effectively weeded out any aspiring astronaut who was less than completely dedicated to space projects. Of course, the competition became fierce and remained so for over 50 years as the astronaut profession became the one most desired in technologically advanced societies. The successful competitors became a new elite group with a commitment to their profession that evolved into a new kind of "religion"; one in which they were viewed as the "high priests"--yet no formal rituals or dogmas were practiced or needed.

The space culture was not planned, it just happened; and as it grew it gradually transcended the former boundaries or "bond" of chauvinistic nationalism. This attitude was not always understood by those outside the "space community" even though it became a prominent theme in the communications media. The direct physical experiences of transcending the surface of the earth had created a psychological counterpoint which led

to a transcendence of the earth-centered national traditions and cultures. The sociological development became one of the major factors which led to phenomenal changes in the 21st century and beyond.

J. Health in Space

In the 20th century it was recognized that one of the crucial factors, perhaps the most crucial, in the long-term development of manned space ventures would be related to their effects upon the health of the astronauts. In which ways would space travel and space-based occupations be beneficial or hazardous to human health? How might the benefits be improved and the hazards reduced? These questions had to be answered. If astronauts had to become sacrificing martyrs then severe limits would be placed on the potential of space-based civilization. Of course, it was known that much could be accomplished in a space program based upon the transient use of astronauts, with each one making a small sacrifice in his health. This would be accomplished by developing systems that were designed to minimize the use of human beings and restricting the time any one of them would spend in the space environment. However, the prevailing attitudes considered such an approach as a fallback position of last resort.

The great task for the biochemists, physiologists, physicians, and other professionals in space-oriented life sciences was to find ways to make the experiences in the space environment, on balance, beneficial in terms of physical health, if at all possible. Numerous problems were to appear, many of which were only dimly perceived at the time of the U.S. Bicentennial, let alone understood. The life science research program

which at first had been only very modestly funded became a huge effort by the end of the century. Indeed it grew relatively more rapidly than most space budgets and by the year 2000 exceeded \$6 billion annually (worldwide).

By that time the major problems had been formulated and various potential solutions were in sight. In fact, by then it was confidently predicted that before long, in a carefully designed program, the health benefits of space-based operations would exceed the impact of the hazards. It was also conjectured over the next 50 years that living in space would become associated with pronounced net health benefits. In fact, the turning point came in the year 2020. From then on the remarkable "exodus" into space became inevitable on principle. Only the timing was somewhat uncertain, since additional technological developments, which were "soon" to appear, were required to give the human race the ability to live almost anywhere in the solar system, and eventually beyond it if they so desired--but more of that later.

The principal health problems that had to be solved initially were the ones associated with prolonged weightlessness or near-weightlessness, those associated with radiation, and those associated with a closed cycle, or very nearly closed cycle, operation of a space station, colony, or "space-ship." One of the great marvels in the history of science is that not only were all of these problems eventually solved, but that as an unanticipated result human beings born in the space environment were to be physically and emotionally more healthy, that their natural longevity is now expected to increase by about 30 years, and that their mental capability, on average, appears to be substantially greater as well. An improved human being, substantially improved, emerged as a result of the efforts

of space scientists and from the natural benefits obtainable in the benign space environment--once routines were developed which permitted an optimized response to the various gravitational forces available to the "permanent" inhabitants of space.

K. Spinoffs

That research and development is a good investment, on the average, is an idea that has always seemed obvious to most of those who value progress through technological and economic growth. For them the ongoing political struggles related to R&D budgets are generally about how much to invest in which kinds of R&D. In this context, one of NASA's early problems arose because its rapid growth, culminating in the sensational Apollo moon landings, were hard to justify to the man in the street on an economic basis. Having won the "race to the moon" at a cost of about \$25 billion (1967 dollars), its budgets were then rapidly reduced in the subsequent decade. In the '70s it was not apparent that the space effort should be sustained as an economically profitable investment in R&D. It was to require more than a decade for the situation to change--that is, for the U.S. public to realize that their past investments in space were a bargain, perhaps the best economic investment they could make at the federal level. Their persuasion came about gradually as the importance of the past technological spinoffs were assessed and as the potential for future technological spinoffs became better understood. After all, the growing importance of COMSATS, integrated circuits, pacemakers, improved weather prediction, and some of the stunning prospecting successes credited to the LANDSATs (to mention a very few examples) alone more than justified

the entire historical expenditures on NASA projects up to the early '80s. After that time the allocation to space-oriented projects began to grow rapidly. As attitudes changed NASA was no longer seen as an interesting but expensive "toy" but as the manager of one of the best investments in the future that can be funded through the federal government. The space program entered the '80s without any major boondoggles to mar its history, while its successes were deemed not less than a catalogue of marvels by most of those who took the trouble to look carefully.

By the early '90s, moreover, many of the important spinoffs had had sufficient time to emerge from the complicated process of developing, testing and marketing. By then economists had developed a conservative method for estimating the economic value of space spinoffs that became widely accepted as a calculation of the minimum impact--even though it portrayed enviable record. In addition, the space program was given credit for important contributions to basic science that could not be quantified but which were publicly extolled as priceless. The discoveries of extraterrestrial primitive forms of life, black holes in the galaxy, and unexpected pulsations in the sun, for example, led to basic revisions in accepted scientific theory during the later years of the 20th century.

Paradoxically perhaps, but not unusual as a theme in man's history, during the '70s funding of space projects was being eroded just when the results of prior efforts were beginning to shower increasing benefits on Americans, indeed on the world. In business language it was being "sold short" just before its true value was about to be recognized. All this changed after the early '80s. By the end of that decade the popularly

accepted "rule" was to emerge from the well-known Apex Institute study that the economic return from prior investments in space technology would yield at least 20 percent per annum for 20 years--and some economists argued that 40 percent per annum would be more correct if the accounting could be done properly. The changing perceptions and attitudes led to the phenomenal growth in space-oriented developments that began in the '80s and was to continue until the present time on a worldwide basis. Private investments grew more rapidly than public ones, but did not exceed them until the year 2045 because of a delayed and much smaller beginning in addition to various political problems. Thus, technological spinoffs of the space program, almost a throwaway concept to NASA in the '70s--a straw to grasp in attempting to justify its existence and restrain the budget trimmers--after 1989 were to furnish some of the leverage which reoriented the public's perception about the economic value of space activities.

L. Milestones

From the viewpoint of space budgets and accomplishments, the last quarter of the 20th century began somewhat slowly but finished with a roar. A perspective on this critical period can be found in the data of Table 16. It was a time of great excitement. Even in the late '90s a few protesting voices could occasionally be heard predicting gloom and doom ahead--but they were growing fainter and fainter.

Table 16

U.S. SPACE DEVELOPMENT MILESTONES

	<u>BUDGET</u>		
	<u>CONSTANT \$1975</u>		
	<u>(X 10⁹)</u>		
	<u>WORLD</u>	<u>U.S.</u>	<u>MAJOR U.S. SPACE ACCOMPLISHMENTS</u>
1976	9.0	3.4	Viking-I & II
1977	9.0	3.3	LANDSAT-C, HEAO-A, Voyagers-I & II
1978	9.1	3.2	SEASAT-A, NIMBUS-G, TIROS-N
1979	9.3	3.1	Shuttle tested in orbit, HEAO-C, MAGSAT, SMM-A
1980	9.4	2.9	Shuttle operational--SPACELAB-1, 2
1981	9.9	2.9	4-stage IUS operational, LANDSAT-D
1982	10.5	3.0	Solar Sail Comet Rendezvous launched
1983	11.2	3.5	1st LEO Space Station begins assembly, Space Telescope launched
1984	12.3	3.9	1st large antenna (100 meters) in GSO, SPACELABS-14, 15, 16
1985	13.5	4.4	Improved Shuttle increases payload, Mars Rover landed
1986	15	5.1	1st Space Base--6 people, Large Chemical Tug operational, International Navigation System
1987	17	6.0	300-meter antenna, U.S. Personal Communications System, Global Crop Prediction System
1988	19	6.8	\$50-Billion Program (International) for SSTO launch vehicle, Saturn orbiter launched, Disease Vectors System
1989	21	7.8	Asteroid Rendezvous Spacecraft launched
1990	23	9.0	Permanent NEO Modular Space Station--50 people, Global Air Pollution Analysis System
1991	26	10.4	1st Space Industry facility (1-MW power), Beamed Energy Tug operational, Severe Storm Prediction System
1992	30	12	1st Moon colony landing (12 people), 1st Fission Tug tested successfully, Advanced Weather Prediction System
1993	34	14	2-Kilometer diameter antenna constructed, Marine Resources System
1994	39	16	GSO Space Station (8 people), Asteroid Sampler launched, Multi-Service U.S. Communications System
1995	45	18	1/2-million lb. payload SSTO HLLV operational, Earth-quake Prediction System
1996	53	21	2nd Space Industrial facility (100-MW SSPS and 150 people), Multi-Service Int'l Communications System
1997	62	24.5	Advanced Nuclear Tug operational
1998	72	28.5	1st test module for L-5 Station launched (6 astronauts)
1999	85	34	1-1/2 million lb. payload HLLV operational
2000	100	40	1st Fusion Tug test, Lunar colony--275 people
TOTAL	744.2	287.0	

OPTIMISTIC SCENARIO

PART II: FIRST QUARTER--21ST CENTURY

A. Economic Growth: A 100-Year Perspective

During the 21st century the explosion of technology, the explosion of knowledge, and the consequent increase in the wealth of the world was, by this tricentennial year, 2076, to reach proportions which would not have been believed possible by 99.99 percent of the citizens of the U.S. a century earlier. Moreover, it is also now clear that this growth will continue. In the tricentennial perspective mankind's destiny appears to be far different from any which was visualized a 100 years earlier--except for a few scattered projections by some science-fiction writers and futurists. The changes that occurred in the world between 1976 and 2076 were massive and pervasive, if somewhat uneven in their effects upon various cultures.

The gross world product per capita in that 100-year-old period, to the extent that such comparisons are meaningful, reached about \$25,000, in 1975 dollars. That is, on average a family of four now has an income which 100 years ago was associated only with millionaires. Of course, the bulk of the world's population then was still associated with relatively underdeveloped countries. However, these cultures have made enormous progress and through increased productivity have reached \$10,000 per capita--an astonishing and tremendous improvement from the near subsistence levels of the 20th century. Moreover, it is clear that they are closing the remaining gap rapidly. Various underdeveloped nations had differing and somewhat gloomy "prognoses" during the late 20th century. However, after extensive assistance from the more advanced countries

became constantly available, few doubted that more than two generations--roughly 50-75 years--would be needed before the former cultural distinctions would be relegated to history.

After 2020 the prevailing ethic among the advanced cultures encouraged each human being to become an integrated member of the emerging Solar Civilization, as optimally as possible in accordance with his or her heritage and innate talents. However, the advanced societies were only encouraging not demanding. Those who wished could choose instead a lifestyle which was variously described as hedonistic, humanist, traditional, contented, or natural. Poverty or crime caused by inherited mental defects or impoverished environments found in most cultures of previous centuries was to all but disappear by 2050; thus choices could be made without duress. Also, little resentment was expressed between those who felt themselves attracted to the outward-bound culture and those who chose the more relaxed lifestyle of the earth-centered cultures. These more traditional cultures did continue to have to cope with crimes that tend to develop in relatively permissive societies which unconsciously encourage what was called the "weak superego" in the 20th century. Thus cheating, vandalism, theft, and some violence still occurs--but much less than before, and it does not spill over into the technological societies.

B. The Computer--Once More

The electronic computer which had not only made rapid technological change possible but inevitable, as is now obvious to all, by about 2025 reached its nearly ultimate capability in terms of hardware. That is, by

then its various designs had approached near enough to theoretical limits that these limits would preclude more than another factor of 5 in speed and another factor of 10 in memory density, or another factor of 10 in reliability. Indeed reliability by that time had increased to the point that the probability of failure caused by random external disturbances which might affect some component of a computer--disturbances such as penetrating cosmic rays or meteorites in space applications, for example--often determined the basic reliability of the system.

By 2025, in addition to near-optimum reliability, the figure of merit of computers* was about a thousand times greater than that in 1976. But this exceptional hardware did not imply the end of progress in the computers' usefulness. In a major sense it was just the beginning. Increasing accomplishments were to arrive in an endless stream in software and in computer architecture, that is in the programming, and networking of large arrays of computers--as well as in ingenious adaptations to automated processing, product design, robotics, and problem solving--adaptations which some people termed "artificial" intelligence even though the distinction between artificial and human intelligence has become increasingly blurred over time as the human-computer interface became more and more intimate or intertwined.

The earlier fear that a computerized civilization would make humans become "mechanical" has become an amusing recollection about one of the myths of earlier history. The sense of freedom, the quality of life, the

*A practical figure of merit is related to the computer's purpose. Generally it is based on a formula related to processing speed, memory capacity, access time, data transfer rates, weight, volume, and cost.

excellent physical health including the elimination of all bacterial and viral diseases, the conquest of birth deformities and the ability to prevent or release individuals from mental "boxes" such as autism, schizophrenia, and severe neuroses; these all came about by the year 2025 because of the computer. Within the dominant knowledge-oriented culture the improved mental and emotional health helped to create a better environment in which each individual's productivity could be tremendously enhanced--especially as the physical resources needed to assist individual productivity were also constantly increasing.

C. Space Developments

1. Infancy to Adolescence

The second half of the 20th century is now generally regarded as the infancy of space developments. During that time the utilization of space for science, exploration, communications, earth observation, and industry was shown to be possible and the first steps into space were taken as the earth-based infrastructure was being created to support the expanding program. It is logical to surmise that in those early years a series of marvels or "miracles" was occurring. For the first time ever human beings were actually leaving earth for missions in outer space after countless millennia of surface-bound existence amid strife-torn civilizations. This period of space infancy was followed by the "adolescent" quarter, 2000-2025, during which the excitement of space was picked up by a new generation whose heroes from childhood had been the "captains" of the great spaceships (the successors to the Saturn V)--but captains based upon the reality of space exploration instead of fiction.

This quarter was to be one of accomplishment, investment, and growth that would reorient the cultures of the entire world and that would offer the tangible evidence that any culture needed to understand that its future could be secure and its horizons essentially unlimited. As one small example, it was in this quarter that weather prediction and general climate forecasting became sufficiently accurate that a new sense of confidence came to prevail throughout the world. "Knowing" the weather accurately for a day or two was pleasant and, in a few specific cases, vital. But of truly great importance, especially for the less developed nations, was the new capability to anticipate long dry spells or unusually heavy precipitation weeks or more in advance.

Earth-applications satellites matured into huge commercial enterprises that furnished "indispensable" services. Unanticipated earthquakes became memories. Precise navigation became cheap. Collisions of ships or aircraft virtually disappeared. No company explored for minerals without first utilizing the processed data from space. No one any longer feared being lost in a remote mountain or jungle (all the wrist communicators and the backup "emergency-beepers" as well would have to be smashed--a million-to-one probability).

Long-distance communication, over 10,000 miles, came to cost about the same as short-distance communication of one mile. In either case the signals traveled about 50,000 miles. But it was cheap and people used it a lot--picturephone or audio as they wished. Holographic imaging was also readily available, but more expensive, for situations where accurate 3-D was important enough to justify the cost.

What became particularly fascinating were the large space structures and the automated machines that maintained and serviced these units. The weird-looking array of teleoperators that replaced malfunctioning modules and the preprogrammed robots that restored the functions could be watched in action and entertained a surprisingly large audience. The earlier (year 2000) estimates for the number of humans required for maintenance of the large space-based communication systems were reduced by more than a factor of 10 by 2025--partly because of greater reliability, partly because of unanticipated advances in automated maintenance.

The huge space structures themselves outshone the former wonders of the world. Many of them were several miles long in each direction; they were the size of cities with symmetric geometries. However, they were gossamer thin at close quarters and on earth would have been quickly destroyed by a light wind let alone any rain, hail, earthquake, or many other energetic phenomena associated with the earth's surface.

The array of functioning space vehicles had entered a long-term trend of improvement and diversity--in accordance with specialized applications--that was to constantly increase the operational efficiency. By 2025, for example, launch costs to NEO had dropped to one-third of those at the year 2000. This reduction coupled with increased income had made space tourism a booming enterprise. As the need for human attendants for space maintenance and repairs decreased, the demand for human "space guides," as those who came to space to facilitate the tourist industry were labeled, grew almost as fast as tourism itself. Before the end of the quarter the first space hotels, hospitals, and museums were functioning and also, of course, the inevitable interplanetary races and other

space sporting events (such as zero-G acrobatics and winged slaloms for "indoor" competition) were burgeoning.

2. Space Industrialization

The quarter also witnessed the great initial surge of space industrialization, the growth of which was to expand exponentially as the unique properties of space were coupled with advancing technology, decreasing transport costs and man's ingenuity to create a vast array of space products and processes. Eventually this was to lead to the construction in space of computer systems, laser communications, technological instruments, robots, cryogenic engines, space vehicles, beamed power systems, and then large orbiting colonies, to name a few of the "products." The raw materials, of course, were to be increasingly obtained from lunar and asteroid sources--although the latter was just beginning to be significant by 2025. The major industrial emphasis was to be increasingly focused on better robots, the automated or "intelligent" machines which were to do the really difficult work without complaint or politicking and which, once developed and debugged, tended to function extraordinarily well in the non-corrosive environment outside the earth's envelope.

This was the quarter in which private investment in space-based ventures replaced the former glamour industries on earth--in countries (such as the U.S.) which encouraged private ventures to function in space. Although many individuals "struck it rich," that was to become less and less important. It had become exceedingly clear that the benefits of space development and its spinoffs would accrue to all of mankind and this fact, coupled with a great reduction in economic insecurity almost everywhere

on earth, led to a growing degree of international cooperation that would have amazed the maneuvering politicians of the 20th century.

The first quarter of the 21st century was subsequently dubbed the Great Awakening. People almost everywhere in the world "awoke" to find that they were no longer to be poor; no longer to be threatened with diseases or illiteracy; no longer to be victimized by weather, earthquakes, or other forces of nature; no longer to be isolated from other human cultures; no longer to live in fear of external invasions or of being sent to war; and no longer to be unwanted dependents. The shackles on mind, emotions, and physical health, were to be rapidly discarded--at least for the children. All but a few of the most remote and isolated cultures participated in this awakening, and those remaining few were "soon" to join in.

By 2025 the world's investment in space ventures exceeded a trillion dollars annually--a sum which if predicted seriously 50 years earlier might have caused belly laughs or a call for a straitjacket. Yet it was even constrained at that time, not by bureaucrats haggling over budget allocations but rather by the physical limits to expansion which were demanded by careful engineering and sequential decision-making based upon tests and performance. It would have been non-productive to have spent more. However, the expenditures on earth for health, education, and training of the new generation, although not directly oriented toward space, were to provide the capability for the rapidly expanding space-oriented projects for a long time to come.

3. Colonization

The first of the "large" L-5 colonies was started in this quarter (in the year 2020, designed for 2020 inhabitants). From its inception it was known to be an experiment whose failures or difficulties would provide the experience which could pave the way for an enormous future expansion. The stable L-5 region was clearly one of the preferred places for testing the concept that large space colonies might become one of the great developments of the Solar Civilization and provide a stepping stone toward the more advanced concept of large colonies which could travel anywhere in solar space--perhaps even further, eventually. Naturally immense unforeseen problems hampered the project during both its construction and "debugging" phases. It was not until the year 2035 (15 years later) that all the important problems were solved and a rapid expansion of the L-5 colonies could begin.

The same kind of difficulties did not attend the lunar base program which expanded rapidly during this quarter. By 2025 there were 14,000 lunar colonists engaged in an array of unique projects. The scientific ones emphasized astronomy, geology and closed-cycle agricultural research. The technological ones concentrated on exploration, mining, food production, surface transportation, and the now-famous electric-launch facility which was first operated in 2017 and initially could "catapult" 2 tons of moon-processed material per hour into space for use in earth-orbiting space stations or at the L-5 colonies.

Although planetary exploration by automated probes and vehicles was a continually expanding program the manned exploration of the planetary bodies was to furnish its share of spectacular adventures as well as

practical applications. By 2005 the first humans orbited Mars and landed on its two small moons, Phobos and Deimos, to set up a fuel depot, telescope and a small laboratory for observation and communication purposes.

By 2025 1,000 astronauts were exploring some distant planetary bodies (the asteroids, Mercury and Mars) and observing others from orbiting space stations where landing was not feasible (Venus, Jupiter, Jovian moons). These were courageous groups of people risking life and health at the farthest frontiers in the spirit of true pioneers. The superb chronicle of their adventures is now taught to every child showing an interest in space exploration. In retrospect it appears astonishing that 95 percent of those explorers survived--although 15 percent of them had to be rescued at least once.

Each tragic loss was an occasion for grief and subsequent agonizing reappraisal. Each successful rescue, on the other hand, was followed by a public celebration and a burst of renewed confidence. Neither the astronauts nor the public had previously expected the survival rate among the explorers of distant planets to be as high as 90 percent. Consequently, despite the gloom surrounding each disastrous event, the remarkable survival rate and the drama of the successful rescues allowed the public to accept the risks involved.

D. Life Science in the Space Environment

As indicated earlier by the end of the 20th century a growing confidence had appeared among the life scientists dedicated to improving the health of space inhabitants. This confidence was bolstered by the large budgets devoted to their purposes. By the year 2025 the scientists believed that they had "solved the critical problems" associated with

prolonged missions in space. The solutions were complex in the sense that the same procedures did not apply to everyone who was to spend six months or more in space; rather there were, generally speaking, three major categories into which individuals could be placed depending mostly upon age, natural variations in adaptability, and prior exposure to the space environment. For those who were best suited to space and who began their careers in a weightless environment before they reached 24 years of age there were no limits to the amount of zero-G exposure--only a requirement for a certain exercise regime and an appropriate diet. Those in the most sensitive category were generally past 40 years of age with the least acceptable natural adaptability; astronauts in this group were required to spend at least 20 percent of their awake time in a 1/4-G environment--again with a suitable exercise and diet program. The intermediate category required 10 percent of their awake time at 1/10-G or more. Those in the latter two categories usually obtained their minimum G-requirements in the artificial gravity of rotating space structures.

The above "solution" was an extremely satisfying one because it resulted in a small health improvement at the 95-percent confidence level and equivalent health (compared to an earth-bound existence) at the 99-percent confidence level. Thus the space experience for nearly every astronaut offered better health as an added bonus. More importantly, the inference could be drawn that over time the relative health benefits of living in the space environment would continue to increase. As these benefits became more substantial they tended to encourage additional outward migration.

Exceptions to the health improvement involved various specialties: for example, it included those who participated in space exploration or in space races. These people accepted an unusually high exposure to space radiation in pursuit of their careers. It was a health risk that could be calculated and kept within reasonable limits but it entailed irreversible costs. Another group were the rescue and maintenance astronauts who were called upon to perform emergency duties beyond the capability of the robots. Again, radiation exposure beyond the limits set for standard situations (space stations, lunar colonies) was the principal hazard; separate (lower) standards were set for these specialists.

Almost as important for the long-term future of space was the confirmation during this quarter of the feasibility of closed-cycle "agriculture" for large space stations or colonies. This development made possible the extensive colonization at L-5 and opened the way for long-term (greater than 5 years) exploratory missions to various planetary systems by large numbers of people. Indeed it opened up the path to the eventual colonization of any habitable portion of solar space (which as was later found did not exclude very much) and any habitable planetary body.

E. Tourism

Perhaps, as much as any other index, the number of tourists to visit space each year provided a measure of the growing interest and the economic development in space. The number of tourists increased by about a factor of 200 during this quarter--reaching 100,000 annually--and was constrained by capacity limits not by willing travelers. The combination of increasing per-capita wealth, decreasing travel costs, and high standards

of safety assured a boom in this fledgling industry for the foreseeable future.

During the quarter the cost of a two-week tour including both geosynchronous and near-earth orbits fell to \$50,000. Moreover, higher priced tours became available, including a lunar journey for some of those who could afford the \$400,000 fare. Still, not everyone who was willing to pay could purchase a seat. Preference was generally given to those who were active in the space enterprises, including relatives--a policy which led to some grumbling among those who were frequently disappointed. To accommodate some of the younger or less affluent people who were eager for a space tour a nonprofit lottery system was established in 2010 that enabled between 200 and 500 lucky people each week to visit outer space. Lottery tickets, at \$100 each, became popular gifts.

Most people could enjoy space tourism vicariously through comprehensive video programs, some of which were holographic when a 3-D effect was feasible and desirable. Indeed such programming was a significant part of the education of youngsters interested in the space-oriented culture. But everyone knew that the truly deep aesthetic experience was only available out there in orbit.

F. Demilitarization

The growing cooperative nature of the international space program had created some alarm in the latter part of the 20th century. The technological advances had produced a capability for very destructive weapons, as well as for constructive developments. Fears that almost any space installations could be quickly demolished by distant death rays might have created a serious impediment to space development. However, the

demilitarization of space began to be effective after the celebrated "Solar System Treaty" between the NATO and Warsaw Pact countries was negotiated in 1988 and signed by all participants a year later. By the late 1980s the felt need to extend the burdensome military establishments into space had weakened. Partly it was because of the high cost but, more importantly, it was because of the emerging worldwide sentiment that wished to establish a peaceful future in space developments for all nations, for all mankind. The now-famous treaty is seen as a turning point, not only for space programs but also for the subsequent waning of the large national military establishments on earth. After 1987, the confidence in successful solutions to the energy, mineral, environment and food problems of the 1970s grew rapidly and led to stable and prosperous economies. This outcome coupled effectively with the new spirit of international cooperation in space efforts, tending to remove earlier incentives for promoting violent solutions to political problems and especially for exporting such solutions. Thus, unexpectedly, 1989 came to be seen in retrospect as the turning point for the demilitarization of the major national powers and alliances. This change did not occur quickly; it began with a slow shrinking of military budgets and over time, almost imperceptibly, the earlier compelling logic for the maintenance of huge arsenals gradually disappeared. Nations did not reduce their military R&D establishments, nor did they stop building prototypes of new weapons and maintaining intelligence organizations. But the overall strategic tone gradually changed to reflect a new worldwide version of political realities. The interest in nations conquering nations had in fact vanished long before 2015, by which date it was fully and overtly

recognized and accepted as an obsolete notion. There was, of course, a general understanding that the rise of "another Hitler" was not impossible in principle, and that a worldwide sensitivity was needed to assure that such a megalomaniac could not achieve control in any of the leading national powers. Even this fear, however, was to be essentially eliminated by 2025, partly as a result of the progress in the life sciences which could assure the basic mental and physical health of all citizens through the prevention of genetic defects in new births. Thus, by the end of the first quarter of the 21st century the world discovered that peace on earth (i.e., war avoidance) had evolved and had become part of the new style of life almost "by itself"--or so some claimed.

OPTIMISTIC SCENARIO

PART III: REFLECTIONS ON THE HALF CENTURY BEFORE THE TRICENTENNIAL

A. Maturity of Space Development

The 20th century was described as the infancy of space development and the first quarter of this century as its adolescence. It is now felt, to continue the analogy, that the world has reached a maturity in space during the last 50 years--however much this may appear to be nonsense a century from now. After 150 years of continued (some say amazing) growth some of us do feel a kind of maturity. Children today accept space travel as simply natural, much as children of the 20th century came to accept automobiles and aircraft.

During its early period of development (i.e., in the 20th century) annual space budgets in the developed nations were often thought of, strange as it now seems, as a kind of sacrifice; or sometimes as an entry fee to an exclusive "club"--composed of those nations with organizations devoted to the study of space science and advanced cosmology through actual exploration. Ordinary citizens often had little inkling that there was much to be gained from this effort beyond a few planetary rocks and some astronomical observations which they had been told were important, though they had difficulty understanding why.

Today the rich rewards of the early efforts are apparent to everyone. The frontiers of space exploration have been pushed far beyond our most distant planet, Pluto, and the resources of space are being ingeniously utilized for the benefit of humans everywhere in the growing Solar Civilization. Former space budgets are now only called investments, and they have had a long record of economic success. This year, with \$20

trillion from earth sources and \$30 trillion of income from space production being reinvested, the total of \$50 trillion for space development is roughly 10 times greater than the gross world product was a century ago. During that Bicentennial year the U.S. Congress was debating whether the (reduced) budget for NASA should be \$3.6 or \$3.7 billion. This year the U.S. will invest over \$11,000 billion.

B. Social and Economic Progress

By any historical standard, prior to this century, the world has become relatively very wealthy in a very short time. Poverty, crime; and disease no longer have the meanings which existed "way back then"-- during the U.S. Bicentennial, for example. Poor people today are so labeled because they choose to be poor; that is, to live in the "style of their forefathers" without the benefit of hundreds of robots, without specialized knowledge, without participation in most of present technology and, naturally, disdaining space travel. Of course they are well provided for in terms of food, housing, surface travel and health care; and most of them are involved in their own forms of arts and crafts, sports and recreation. Generally these groups are held together by their religious convictions although a few claim to be purely hedonistic. Yet they have been a steadily diminishing portion of mankind and now constitute less than 20 percent of the total population.

The earth's population is now 9.4 billion people and is expected to remain stable. The population living in space, now at 40 million, is small compared to this number but it is expected to continue to grow for some time. Since our world product is about \$290 trillion (260 on earth,

30 in space) the GWP per capita is almost \$30,000. Moreover, except for those who are poor by choice the income gap has shrunk considerably from that of a century ago. Today even the South Asians and Chinese are well to do with an income level about 40% of the world average. Even this lag is mostly due to the fact that there is still a high proportion of them who did not have the opportunity for a thorough education when they were young-- a situation that does not exist today.

Every child born after 2050 has been free from mental or physical defects and (again excepting those who choose a traditional existence) will be raised under ideal circumstances as they can best be defined. Thus, by 20th century standards each child today is expected to develop into an intellectual genius, physically in nearly perfect condition, emotionally alert and responsive without neurotic instabilities, and currently may expect to live at least 120 years with 80 of them being highly productive. Consequently, nearly every child born after this year is likely to be active during the celebration of the U.S. Quadricentennial, the nature of which I will speculate about later on.

C. Automation

The first 200 years of U.S. history more or less coincided with the industrial revolution. Thus, since the time of the American revolution, people in technologically advancing cultures have devoted increasing efforts to developing, maintaining, and operating machines. During the last century this has not changed in principle, only in its qualitative and quantitative nature. Of course, the world today would appear puzzling to almost anyone from the Bicentennial year. For one thing there

are no observable pollutants resulting from industrial enterprises. Indeed, most of us now live without even the background noises of the former civilization--with a few exceptions that are transitory experiences. But today nearly everything called work 100 years ago is done by highly automated and often "very intelligent" machines. Wherever the local environment is unsuited for human comfort the human interaction with these machines, or robots if you will, is communicated electronically from an appropriate distance. Maintenance procedures are automated and specialized maintenance robots are designed to function reliably, even in the more challenging environments.

Most human beings today specialize in knowledge and skills of the kind that computers or robots do not yet have. Each person has many different kinds of "personal robots" to assist him in his work, in addition to those which he shares with others (like the space vehicles or the computer networks). Scientists generally have access to whatever instruments or computational facilities they require--although where expenditures are required beyond those authorized by existing standards, peer-group permission must be granted.

D. Computers and Electronics

A few more remarks about computers are in order before we get back to space. It would be almost impossible to describe to a person from the 20th century what changes the computer-based sciences have wrought. Perfect human health--mental, physical, and emotional--is a "computer product." That is, like most of present technology, it is possible only because of computers. Present computer systems are optimally designed

hardware components netted together in a worldwide electronic grid which simultaneously is both private and intimately public, as befits a good system. Thus any information anywhere about any subject that has been connected to the grid is quickly available to anyone through electronic information transfer--as is access to any person anywhere in the solar system--when access is mutually desired.

Even today, though overall "efficiency," or figure of merit, of the electronic computer network is estimated to be about a million times greater than it was at the turn of the century, the experts believe that there will be astonishing improvements during the next 100 years--or for as long as people desire it, some believe. It would probably have been very difficult for an informed citizen in 1976 to anticipate that after a mere 100 years the computer power available to each individual would exceed the total computer power of the world in which he lived!

E. Planetary Population

The population in space is evidently going to continue to expand for some time. On the moon today there are about 10 million people, perhaps half of whom spend more time there than on earth and who have come to prefer it, mostly because of the exhilarating low-gravity environment. Some people are predicting that the lunar population may eventually exceed a billion. Certainly there are no major obstacles to this occurrence, only the debate about the lunar atmosphere. But with a billion residents, the amount of gas leaking from their "closed environments" and from lunar industry may become so great that the moon may acquire a sensible atmosphere--a potential annoyance to lunar astronomers as well as manufacturing processes requiring high vacuum, if it occurs. However, most people feel

that there are enough alternate platforms for observatories that it would be better to move some of the astronomers than restrict lunar development. Others believe the leakage will be adequately contained.

Lunar materials are coming into increasing demand for space stations and colonies and the mining activity is apt to grow rapidly for several decades or more. The colonies at the L-4 and L-5 points have a population that equals that on the moon and are the most rapidly growing region for space habitats and industrial facilities. Within the next few decades almost all space vehicles (except SSTOs) are likely to be produced at the L-colonies. These two regions are evidently destined to become the great industrial parks of the extraterrestrial Solar Civilization--at least that is the way it appears now.

Meanwhile the space frontiers are being expanded by the exploration teams. Mars has about 25,000 people in its colonies now. Its lower gravity is pleasing to the surface residents, the more enthusiastic of whom predict that Mars will one day be engineered to provide climatic conditions suitable for the introduction of several kinds of flora and fauna. Today it is mainly used as a scientific outpost but it also produces a substantial quantity of fuel for vehicles which are recharged in the Martian orbital stations.

The rest of the 200,000 exploring astronauts are well scattered over the solar system. Each planetary body is to be exhaustively investigated--by robots alone only where the environment is too hostile for human presence. By now all of the large asteroids have been examined and catalogued. Some of them will be dismantled during this coming quarter to provide fuels and minerals for the planned Asteroid Industrial Park.

Chunks of the more valuable asteroids, of course, are even now being moved regularly to the L-colonies; this freight has increased about 100-fold since 2050--last year 100 million tons were catapulted into space.

F. Space Vehicle Developments

The most impressive achievement during the last decade was the new non-radioactive fusion engine which operates at an efficiency of 80 percent to 90 percent--that is, at least 80 percent of the fusion energy is available as electric energy if desired. In an alternate design the fusion products may be directly ejected from the engine without electrical conversion. This engine makes it possible for very large space vehicles to travel economically at great speeds and is particularly important for missions beyond the asteroids. The manned exploration of the distant planets and their satellites will be greatly increased because of the power and efficiency now available.

Perhaps even more exciting is the potential, which now appears to be quite likely, that during the next few decades advanced versions of the fusion engines may open up the possibility of manned interstellar exploration--a persistent dream among the more devoted buffs of the Interstellar Exploration Society--one that some of them claim will become reality within the next 50 years!

Although by using a kind of rough averaging we estimate that the cost of space transport has fallen during this century to about 1/5 of the cost at the year 2000 (about \$4 per pound for a launch to near-earth orbit of a vehicle containing human beings), there exists such a large array of special-purpose vehicles that statistical averaging obscures some of the important economies which are achieved by specific designs.

Also, the transport of human beings costs from 2 to 20 times more than that for most inanimate materials. Also, transport time is sometimes an urgent consideration and other times not. For example, in transporting lunar raw materials or chunks of asteroids, the rate of arrival at the space industrial center is usually the dominant factor, and whether the travel time is a week or a year is much less important--especially because robot-time is usually much less costly than human time in the relevant systems. This is the reverse of the 20th-century relation in which automated machines or central computers were generally worth much more than human labor on a cost-per-hour basis. A competent engineer is now paid roughly \$1,000 per hour, about 100 times more than his counterpart a century ago, while the value of "equivalent" 20th-century automated machines, instruments, robots or computers has fallen by a factor of 10 to 100--if indeed the use of the term "equivalent" in this context has much useful meaning today.

G. Tourism

Because of the steady drop in costs the phenomenal growth of space tourism has set a new record reaching 200 million tourists last year. The average length of time per journey is now over 30 days and the average cost for a trip which includes 10 days on the moon is about \$50,000. Space tourism currently is a \$10-trillion annual business--about twice the entire world's GWP a century ago, and perhaps 20 percent of the total expenditures in space development projects. A "standard" tour might spend several days in various earth-orbiting space stations and industrial complexes, a week at one of the L-colonies, about 10 days on

the moon and a few days visiting space museums, sports stadiums, and examining some special features such as power stations, exploration vehicles, space robot displays, giant laser-communication centers, or astronomical observatories. Many people have found that their greatest single spiritual experience was spending several hours, or days, in a space suit, orbiting by themselves--especially the first time it was tried.

H. Interstellar Exploration

Some interstellar buffs keep redesigning the space vehicles which they believe will soon set out to investigate one of the nearer stars with a human crew. The estimate (in 2060) was about \$8 trillion for a vehicle with 20 people which might, with luck, make a round trip safely in about 150 years. While still too expensive it is commonly believed that within 50 years the first such mission will be undertaken, perhaps even with a larger group--since none of the original starters may be among the finishers. None of the problems seem insurmountable, only costly, dangerous, and of questionable value. But when the total cost comes down to less than 2 percent of the GSP the first star-bound adventurers may prevail.

One-way scientific missions with robots are now being launched regularly toward interesting stars, black holes, and various anomalous regions within a 100-light-year radius. Scientists are eagerly awaiting the returns from the first contacts which will occur in about 5 years, although it will take another 4 to 10 years to get the information back through the interstellar communication network, which the robot explorers are still installing as the probes reach out toward their destinations.

The black holes, of course, are still tantalizing the astrophysicists. Several thousand black holes have now been positively identified and the theory of their formation, sizes, and distribution is now well understood. Still the physical laws applicable to the processes within these holes have resisted the most ingenious attempts to understand them. For this reason the data that might be returned by the first probes approaching a black hole are eagerly awaited and, some believe, might revolutionize some of the basic theories of physics soon after they are received. Who knows what that might lead to?

Powerful astronomical instruments have mapped our galaxy with much detail. Of the planets as large as or larger than the earth that exist within 500 light years of us, probably 90 percent have been identified and catalogued. At least 10 percent of them appear to have a potential for some form of life and perhaps 12 planets are considered to offer conditions that make advanced life forms possible. Only one of these, however, is near enough to be reached by one of our probes within the next 50 years. Still the sensitive receivers of the interstellar communication system will be constantly listening from now on--and the system will be continually expanded into deep space along many directions.

1. Solar Civilization Government

Even though certain residual traces are still present, the former nation-state system has largely been supplanted by the solar civilization and the new institutions of present societies. With the elimination of poverty, crime, disease, insecurity, and war during this century and with the expansion into both the space frontier and the earth's oceans

(25 percent of the earth's population now live on floating cities) many of the traditional functions of nations were no longer useful. To what nation children born in space or in ocean cities should "belong" was a concept that simply eroded away. Language barriers were quickly transcended early in this century with computerized translators and eventually the logical language of our present civilization became the common central one. Of course, many people are still facile in the languages with which they were raised and the remaining "poor" people speak their traditional languages by choice.

But our present "government" would be incomprehensible to our great-grandparents back in 1976. In those days politicians of democratic countries pretended to be the "servants" of the people when in fact they held the power of masters and often used it viciously or stupidly, sometimes covering up their real motives until they deceived themselves more than others. None of this is possible today. Dishonesty is no longer needed or useful; it is hard to find and carefully exorcised when it appears. Governing today is serving the people and is not one of the exalted professions. Effective power exists in real knowledge and in physical skills; no longer in hypnotic propaganda, wealth, or traditions. Our society knows that the astonishing foolishness of people's behavior prior to this century has become only a memory--a set of recorded events, unlikely ever to be repeated. It is difficult for young adults today to believe that they have only so recently, and luckily, emerged from the long era of "jungle" civilizations.

Today life is a glorious 120-year adventure for each citizen. Death is considered no more of a tragedy than a long sleep would be--except for the chance fatal accidents and these are quite rare. Our fellow human beings, whatever their origins or destinations, are always a pleasure to meet and to interact with. Today this is how people believe it should be.

OPTIMISTIC SCENARIO

PART IV: FORECAST

A. Future Exploration

Now what of the future? There have always been those who believe that mankind has gone about as far as it can--but these opinions are not too numerous now. For most space professionals, today, the gist of the future potential of space exploration is summed up by the phrase, the universe beckons. This phrase goes beyond the mere human visitation to other stars or their planets--an accomplishment not yet achieved but believed quite generally to be one which will become routine and whose beginning is even now on the drawing boards. More about these ventures later. Now we simply want to establish more fully the meaning of that phrase to the current generation.

It is taken for granted that the development of the solar civilization will continue in many of the directions now clearly indicated. All accessible planetary bodies will be mapped, explored and colonized by humans where this is feasible and by robots where (or while) the environment prohibits human access. Massive planetary engineering will be a constant potential program for each planetary body, whether it is a small moon or great Jupiter, itself. But there will be no great hurry as such undertakings at present are interesting more as scientific investigations than as economic or social requirements. Even in their early stages such projects (assuming that in the efficiency of space travel the expected sustained technological advances do occur) should make the trip from earth to Jupiter, or even the outer planets, a frequent

"routine" journey less arduous by far than the sailing trip from England to the U.S. during colonial times.

Travel in the solar system is now readily available for anyone who desires it and living in space is a commonplace experience for tens of millions of people; we expect the space-based population to expand to several billions within the next hundred years. Wherever large groups of space explorers travel they can choose to take with them complete closed-cycle systems for comfortable living, including the required portable space industries, all with operating and maintenance robots. The necessary operating information would be stored or made rapidly available through the laser-linked communication systems. Thus the only significant communication or information delays between planetary communities are the inevitable ones caused by the time it takes light to travel the intervening distances.

Perhaps (and this is a personal view) the shape of the future expansion of our civilization into space will be somewhat analogous to a slow motion unfolding of a gigantic explosion which would gradually reach outward in every direction. Thus, some people today visualize that self-contained, self-sufficient communities (containing between thousands and several tens of thousands of people, each person with hundreds if not thousands of specialized robots) will gradually expand, first throughout the far reaches of the solar system--and then beyond that--maintaining continual communications (indeed, while developing the interstellar communication network) but generally roaming farther and farther from the solar center. The enormous energies available near the sun will become less and less important, as even now the energy needed can be plucked

from the outer planets, soon from any passing comets and other space "debris," and finally even from the diffuse hydrogen atoms of space, if need be. The energy from fusion, coupled with efficient recycling of matter inside each colony, should provide the bulk of the requirements for almost any journey--even one to distant stars--that is now contemplated.

In this concept of an expanding space-based civilization the design of complete systems for interstellar voyages appears likely to be substantially different from those generally visualized prior to this century. Those concepts, usually involving speeds approaching that of light and possible round trips within a lifetime, are now deemed appropriate only for vehicles operated purely by robots--many of which are already proceeding at optimum speeds to the nearer stars. But voyages of colonies of people will take much longer and are likely to be part of the general expansion into the galaxy, while maintaining intimate communications with all neighboring communities (those within a few light weeks or so). Thus the present image is one of armadas of large self-sufficient space colonies regularly emanating "radially" outward from the solar system, maintaining intimate contact through laser communication, drawing their energy requirements from the endless resources of space and continually developing the community organization (and the individuals within it) while the grand voyage proceeds. The first destination of the journey, which in itself clearly is an endless one, can only be the first objective of the expedition. The journey itself would simply be the physical path in space-time that the community will be following as it proceeds about

its business of living, learning, and interacting with the other communities of the expanding solar civilization.

The above image, of course, may change greatly during the next hundred years. It is simply considered to be the most likely one to develop--according to the present state of knowledge. However, since this grand expansion has not yet begun--nor is it likely to for another 50 years or so at the earliest--who can say whether it will come about as described? After all, there are still some who contend that even the "impediment" of the speed of light may yet be overcome when we have delved still further into the scientific secrets that nature only gradually reveals to us a bit at a time. That alone could, and many believe will, usher in an incomprehensible new universe of discoveries that would make the above image of the future appear to be naive--or primitive.

The awesome aspect of looking backward in time is the implication within the exponential nature of the knowledge explosion that has occurred over the last few hundred years. If that expansion is projected for another hundred years at the recent growth rate it will imply that, despite our impressive planetary exploration, our current knowledge of the cosmos, and our understanding of the infinitesimal structures of the component parts of matter, that currently we are still infants in knowledge--that the really impressive breakthroughs in comprehension are yet to come. Each of the last four or five centuries has witnessed ever more awesome and radical changes than the one before, at least by one or more orders of magnitude, where numerical measurements are relevant. Futurologists are very excited, yet they must feel a little shaky inside

at what must lie ahead, knowing that beyond a decade or so the future is essentially opaque, even as they try to peer through the thick fog for a glimpse of what is to come.

In a more practical vein projections for the next century, for whatever such exercises are worth (relatively little, judging from past experience), have been made and I discuss some of them now, more in the spirit of entertainment than as a serious guide to what will be.

B. 100-Year Projections

1) First, the population living in space should grow to about 10 billion people in 2176--a substantial fraction, perhaps 10 percent, of whom may be outward bound in the sense discussed above. The 10 billion total is an extrapolation based on a gradually diminishing "exponential" growth of population (see Table 17) and is coupled with our assessments of the rate of future economic growth on a relatively conservative basis. The space population by then will be about as large as the population on earth, that is expected to remain about the same as it is today.

2) Tourism will grow rapidly but will have changed before 2176, mainly because the number of people traveling between earth and various space destinations will increase by about a factor of 1,000. Even now space tourist is a term which is rapidly losing much of its former meaning. Except for first-time visitors most space travel is now associated with specific projects that the individuals are involved with. Whether a large space-liner or personal space vehicle is utilized for the journey is a matter of optimizing the choice. A century or more ago a tourist was a person traveling in a foreign land interacting with an

Table 17

OPTIMISTIC SCENARIO
POPULATION AND GROSS PRODUCT
(PAST & PROJECTED)

<u>YEAR</u>	<u>POPULATION (BILLIONS)</u>		<u>GROSS PRODUCT* (\$ TRILLIONS)</u>	
	<u>EARTH</u>	<u>SPACE</u>	<u>EARTH</u>	<u>SPACE</u>
1975	4.0	—	6.6	
2000	6.0	0.8**	20 (.045)	.02
2025	7.7	60.** (.188)	50 (.037)	.36 (.12)
2050	8.8	.003 (.170)	115 (.034)	4.0 (.10)
2075	9.4	.04 (.108)	260 (.033)	30 (.084)
- - - - -				
2100	9.7	.31 (.085)	720 (.041)	180 (.074)
2125	9.9	1.5 (.065)	1,670 (.034)	900 (.066)
2150	9.9	4.5 (.045)	3,500 (.030)	3,600 (.057)
2175	10.0	10.0 (.032)	6,700 (.026)	12,000 (.049)

* FIGURES IN PARENTHESES ARE AVERAGE ANNUAL GROWTH RATES FOR THE PRE-
CEDING QUARTER.

** THOUSANDS.

unfamiliar culture, usually from a somewhat protected and insulated vantage point (or path). Today cultural insulation is largely non-existent--except among the remnants of traditional cultures that remain so by choice. The knowledge-oriented civilization has no interest in developing tourism as a method of intercultural communication. Indeed, it would generally be an extremely inefficient approach. Information about any aspect of space cultures, as with earth cultures, is generally available quickly and accurately through the solar communication network in any of the desired standard forms (i.e., visual, audio, holographic, symbolic, etc.) or any combination of these.

3) Economic expansion in space is projected to increase roughly by a factor between 100 and 1,000 (the median GSP projection for 2176 is \$12 quadrillion, for those who find such numbers meaningful) compared to a factor of 25 projected for earth--partly because of the anticipated continuation of the relatively unproductive traditionalists, partly because the earth is relatively crowded and investments tend to flow into space projects, partly because the climate and the diurnal cycle on earth constrain optimal development, but mostly because of the opportunities and the resources which exist beyond the earth's atmosphere. The average income of a family of four within the knowledge-oriented culture now exceeds \$100,000 annually and has been increasing monotonically (and almost exponentially) as we all know (Table 17). Since the total population (earth and space) is expected to no more than double during the next century, economic standards in terms of per capita gross product should, on average, increase substantially more than 10-fold.

4) Space travel is soon expected to become much cheaper as the result of several imminent developments. One is the recoverable momentum system which will, in principle, enable travel to be almost free in terms of the required matter (ejection mass) and energy wherever travel time is not a major consideration. For long journeys, where time is important, both the recent anti-matter engine and the constantly improving fusion engines have been reducing costs steadily. We now anticipate that during the next 100 years costs will drop to less than \$1 per pound for transporting people from the earth's surface to near-earth orbit (freight will generally be much cheaper, of course). But the more important aspect of commercial travel beyond cislunar space is the time/cost ratio. It is in this regard that the improved engines will be most useful. Jupiter, for example, will soon require no more than 4 weeks to reach without great expense or discomfort during travel (i.e., at approximately 1-g most of the time) and about half that much time for urgent business, although this latter is not expected to be frequent--at least not during the next decade or so.

5) Perhaps some of the most exciting possibilities that lie ahead of us are related to the interaction of people and computers. As in the past we cannot see, except in vague--perhaps meaningless--ways, what important discoveries or applications are likely. However, informed people continue to speculate upon the possibility of direct linkages between computers and the human brain in order to further improve the human memory, speed up thinking processes, and perhaps learn while sleeping (or even while awake--on an unconscious level). Technology already

has enabled us to make considerable progress in all but the last process, but not through a direct linkage--rather through much better understanding of the electro-chemistry of brain functions, an important part of the foundation of the knowledge-oriented culture. Even now, however, the innate capability of the healthy brain is known to be at least 100-fold greater in terms of memory than that which is usually achieved; and for creative problem-solving ability we still can't make meaningful quantitative estimates; it is only believed to be potentially much greater than that which exists at present. Coupling these expectations with the evolving computer networks and the growing number of effective contributors simply makes the future continue to appear "explosive" in terms of its potential for new knowledge, just as it has always appeared since the middle of the 20th century. More or less consonant with experiences a hundred years earlier, we still find that our information systems produce much more than can be rapidly digested--an inevitable "problem" associated with rapid growth in the system's capacity. But, in retrospect, the progress is astonishing. About 200 million people are now professionally engaged in improving the information and communication system; each of these people also have the present integrated information and computing network available as a tool to help with the task.

C. A Universal Brain?

Naturally, one of the common spectacular images of the future is that of a great "universal brain" composed of all of the brains of the inhabitants of the solar civilization linked optimally into the vast integrated computer network, which by innate design is self-programming

and therefore potentially rapidly self-improving--even as it improves the effective brainpower of its users! Even though today individuals conceive of themselves as independent autonomies--as they always have done in the past--they are more aware than ever of their interdependence through the information network.

The major difference in current attitudes from those which prevailed a century or so ago is that this interdependence is now considered desirable; that rather than promoting robot-like humans this interdependence promotes "human-like" robots where these are desirable and frees human beings to perform ever more creatively in endeavors of their choice. No adult is forced to participate in any project and anyone who so wishes can leave the knowledge-oriented culture without fear of reprisal. It even happens occasionally, although quite rarely. Actually the drop-in rate in recent years was 100 times greater than the drop-out.

Thus, the expectation exists that if the "Universal Brain" does evolve into a meaningful entity it will be an entirely desirable and natural evolution that will undoubtedly completely recast the image of man's role and destiny in the universe. Few people now doubt that over the long term (more than 100 years from now) that the concept of human destiny will come to include the exploration of our whole galaxy through actual visitation--perhaps even other galaxies as well. However, it is in the necessarily murky ideas of what else man's destiny will include that engenders the greatest excitement.

Chapter V

THE NEW INTERNATIONAL ORDERS

PART I: THE CHINESE SOLUTION (A PESSIMISTIC SCENARIO--FROM NASA'S VIEWPOINT)

A. 1976-2000

The New Class

During the '70s the New Class^{*} had become relatively strong in most of the advanced countries. Its influence was expressed worldwide through (a) the rapid growth of environmental and conservation movements; (b) a growing concern about economic disparities within each country and among nations (e.g., the North-South dialogues resulted from this concern); (c) a neo-Malthusian doctrine which opposed most large industrial--especially new energy--projects within OECD countries; and (d) an increasing transfer of responsibilities upon innovators of new products or processes, requiring them to furnish prior proof that any risks would be insignificant, plus the responsibility for damages if they are wrong (i.e., forcing them to buy large amounts of risk insurance if it was available--or to assume the risk themselves if it was not).

The ideology of the New Class, which in retrospect appeared to have sprung into being during the 1960s in the U.S. and developed rapidly during the 1970s and 1980s in the OECD countries, became a dominating ideology and led to a continuing struggle to improve the Quality of Life (QOL) during the balance of the century. To some observers the ideology had a strong religious overtone--that of modern day Zealots, some claimed. It

^{*}See Appendix A.

was not always--or even usually--clear how QOL was to be defined or interpreted since one person's perception of improvement was often at the cost of another's standard of living. The argument that this ideology created disincentives for hard work was brushed aside. Work was to be made desirable, not hard. Hard work should receive extra compensation. To the extent that it was feasible, health, education, economic security, a more equitable distribution of income, and opportunities for a happy life in a clean environment for all citizens were to be increasingly encouraged by government. Indeed, this ideology was, in principle, to be extended to help all other countries--especially the poorer ones--gradually to improve their QOL until they were on a par with the developed countries.

Technology was to be both useful, in providing required material needs, and controlled, to keep it from creating new risks to health and strains on the environment--or on the capacity of nature to provide resources. That technological progress continued to take place under these circumstances was probably due more to the fact that the most powerful tools of technology, the solid state computer, the laser, instruments for automated chemical analyses, automated production, and a revolution in most basic sciences and in engineering had come into being during the 1950-1975 quarter and continued to develop despite growing social resistance. The full impact of this technological revolution was so vast and so complex that even relatively few scientists fully appreciated what was occurring. Thus, the increasing potential for rapid technological development in the most advanced countries was able to compensate for a changing social system which was to drain its funds, its brains, and make its application to new products and processes increasingly cumbersome.

After 1990 the New Class ideology continued to strengthen in the OECD nations, (including Japan, but less so) and started to affect the Soviet Union. The Third World remained relatively impervious to the ideology, accepting only some obvious environmental benefits--but they gave some lip service support where it was to their advantage. Within the OECD the low economic growth rates were rationalized by the New Class as a required sacrifice to achieve an improved quality of life (QOL).

U.S.S.R., China, and Brazil were the relatively successful large (non-OECD) countries that effectively resisted the New Class concepts and which continued to stress economic and technological growth--each in its own style, of course. Each of these countries, as we shall see, was to pass the United States in space development by the early part of the next century--a direct consequence of the ideological differences of their societies.

The great concern about energy shortages within most of the developed countries abated somewhat in the '80s because of (1) an economic slowdown in the OECD countries and a reasonably successful energy conservation effort (after 1978 the energy demand of the developed nations increased on average only 1.5 percent/year); (2) by 1982 OPEC had developed a 10-MBPD excess capacity and considerable infighting or elbowing for markets occurred--a "game" in which the Saudis usually prevailed; (3) very successful exploration for oil and gas in Third World countries--especially in Brazil and Mexico--as service contracts with the major oil companies increasingly became the standardized method of operation, usually with financing help from OECD nations. The reduced demand and increased production were sufficient to meet the energy needs until alternate energy

technologies became effective after the late '90s. The abatement of the energy crisis was interpreted by the New Class as a victory for their ideology while their opponents grumbled about forced conservation measures, inadequate sized autos, and--most of all--economic stagnation, a trend which the New Class favored (and pointed to the relaxed energy situation as evidence to vindicate that policy).

U.S. Progress

Although the GNP in the U.S. increased 50 percent during the quarter century, that represented an average growth rate of less than 2 percent and a per capita growth rate that nominally was greater than zero, but in terms of material consumption was slightly negative--but, according to the New Class more than offset by an overall improvement in the QOL.

In the U.S. the space budget during the last quarter declined, in real terms, about 1/3 to \$2.4 billion (1975: dollars). Science and technology funding also eroded, but more slowly, to about 85 percent of the 1975 level. Innovations became very threatening to many industries where the available risk insurance was inadequate or very costly. Also, where government licensing and/or permits were required the time and effort involved continued to increase, much to the dismay of private industry. For example, the estimated time between the initiation and completion of an electric power installation in the late '80s had increased to 15 years--compared to 3-4 years in Brazil, and 8 years in Japan (in which only a decade earlier it had been less than 4 years). As a result higher unemployment and lower salaries prevailed in most technological areas of

the U.S. By 1990 the beginning of a reverse "Brain Drain" was observed--technologists looked for and found opportunities in the growing Third World countries and in OPEC countries as U.S. employment declined.

Highly successful space programs generally did not create confidence in similar outcomes for future programs whose economic benefits could not be "proved" in advance. The LANDSATs were known to be highly useful but doubt about the value of future improvements prevented their rapid expansion. The remarkable success of COMSATS became embroiled in national debate over the value of excessive communications--in any event they were largely within the province of private ventures. The Advanced Space Shuttle program, proposed in 1982, was buffeted about for 3 years by arguments about the growing risks from the impact of spacecraft launches on the upper atmosphere. It was postponed indefinitely in 1985.

The U.S. space program probably would have been a relatively early casualty of the developing social system had it not, astonishingly, been so successful. Still, it was a rare year that its budget was not reduced, in real terms, although the continuing inflation often made it appear to be constant or increased slightly in successive budgets.

Even though the space program was increasingly oriented towards current needs on earth by designing systems to improve communications, monitor pollutants, predict weather, provide accurate navigation, prevent ocean collisions, find mineral resources, predict earthquakes, assess agricultural production, determine water resources, etc., and generally performed these tasks better than had been first anticipated, it did not keep the space budget from falling. Each success became a new routine service and was soon forgotten by the non-technical public. These services, once

established, were thought of as "free"--that is, it did not require a dollar to be spent out of pocket in order to get a weather report or a measurement of sulfur dioxide concentration. The value of the communications system was buried in the telephone bill, the inflationary changes, and the complicated and peculiarly American system of charging for television services. It was difficult for the public to appreciate the cost-effectiveness of the space program because of its inherent complexity, its dependence on government support, and because hostility to science and technology increasingly came into vogue.

Nevertheless, there were some impressive new successes. The Solar Sail was shown to be effective as a spacecraft which, in 1986, after a rendezvous with Haley's Comet, was sent on a mission to observe the planet Mercury from a near orbit. A large (250-foot diameter) Antenna was constructed in space in 1990, 1 year after a Modular Space Station was established (with 6 people). Roving Landers were successfully placed first on the moon (1985) and then on Mars (1991) to gather scientific data. A small Space Industrial R&D facility with a 100-KW Solar Power Satellite was established in 1993--but the Soviets were well ahead of the Americans by then.

Particularly disappointing to the space specialists was the refusal of the government to fund a large capacity advanced Space Transportation System, a program for colonizing the moon, or a program for testing the feasibility of permanent space colonies (of the type suggested by Professor O'Neill and others). An advanced transportation system, of course, would have been tantamount to a long-range commitment to a large and growing space program. Thus, it was not consistent with the new ideology.

While these changes in attitudes discouraged the space professionals, and indeed the entire scientific and technological community, the American public barely noticed it, except for the leaders of the New Class who were pleased and felt that humanity had been protected from potentially great new risks. In the late '90s many of the more aggressive New Class leaders in the OECD nations came to believe that the time had come to start shifting their efforts to the more successful developing countries and to those of the centrally-controlled economies--especially the U.S.S.R. and China.

Progress in Brazil

The most spectacular economic success during that quarter century occurred in some of the Third World nations, the outstanding example of which was Brazil. The new desire for wealth and power which had been lit in Brazil during the '60s and early '70s developed into an unquenchable national passion that overcame obstacles such as inflation, worldwide recession, energy shortages, heavy indebtedness, and regional illiteracy--obstacles which were effective barriers to many other nations. As a result the Brazilian economy grew from about \$110 billion in 1975 to \$750 billion at the end of the century. Their economic success was greatly assisted by the financing from the more developed nations and by the technologies brought to them by the large supra-national corporations. These corporations found an increasing symbiotic relationship with the Brazilian passion for growth, after which the "honeymoon" became a protracted one.

Brazil's educational system acquired a strong science technology and business orientation. Partly because of profitable internal growth,

but more from the rapid exploitation of huge new oil and natural gas reserves, found during the '80s and '90s, it began to improve its balance of payments situation. The Brazilian universities developed rapidly and soon were enticing the world's best brains with both high compensation and guarantees of adequate research support. The use of the English language in all technical departments of higher education levels became customary as foreign specialists and professors were given the right to teach in English or in Portuguese and almost always chose English. High technology industries were given very favorable treatment after 1980 and foreign investment--especially from West Germany, Japan and the U.S.--continually increased thereafter.

More because of their eagerness for technological progress than for its commercial potential the Brazilians began a serious space program in 1990 which grew 10-fold in 10 years to a \$1.2 billion level, a level that at century's end was within striking distance of the U.S. space budget (\$1.8 billion). This growth became possible because many of their space scientists could be recruited from West Germany and the U.S. In celebrating the turn of the century Brazil projected its space program to increase at least 6-fold during the next 25 years, a level that--if attained--would be roughly equal to the year 2000 budget estimated for the Soviet Union--the acknowledged world leader in space in that year.

Progress in China

Another "sleeper" in the economic growth "race" was China. Because of the customary Chinese tendency towards self-reliance its average growth rate of 6 percent during the last 25 years of the 20th century was noticed mostly by professional China-watchers. Although foreign trade with China

was growing, it did not compare with that of any of the other large nations. Consequently, the developments within China tended to be overlooked or soon forgotten. By the year 2000 its GNP had reached \$1.25 trillion--a very respectable amount and substantially greater, if less flamboyant, than Brazil's \$.75 trillion. Of course, China's per capita GNP was only about \$1,200. But the population had stabilized and the quality of its infrastructure had been kept well balanced as it improved over time.

A quiet Chinese "passion" resided in the traditional belief that their cultural superiority would enable them in time to succeed in any areas that they chose to compete in. It was clear to observers that they were making excellent progress in technology, economic development, science, and in space projects. The evaluation of their quality of life was more subjective and depended strongly upon the values and data selected for analysis by the observers.

The Chinese were destined to become an envied culture in many ways. They had been admired for decades because of their independence, their self-assurance, their conviction of cultural superiority despite their earlier poverty, and their refusal to accept (let alone ask for) outside assistance--even during severe natural calamities. Thus, their interest in space development, as in all matters which to them meant progress, was only natural. The pace of their space program, of course, had to be determined in competition with other demands, but their attitude was simply that that they would become the natural leaders there, too--as in all important cultural developments--in the course of time. The ideology of the New Class had almost no effect upon the Chinese. They interpreted it merely

as a manifestation of a struggle within confused inferior cultures, going nowhere.

Of particular note, however, was the Chinese space program which first appeared noticeably in 1981 when two satellites were launched into near-earth orbit. By century's end they had launched 140 spacecraft (with only 6 failures) and were reliably reported to be testing a reusable launch vehicle which was believed to be able to compete easily with that of the U.S.S.R., which until then had developed the most advanced automated space "freighter." Its budget for space projects, though not publicly revealed, was estimated to have increased to about \$2 billion annually and in the year 2000 therefore exceeded that of the U.S. The trend toward space development in China was less flamboyant than that in Brazil, but more secure in that it did not depend upon foreign assistance. There were at least a few observers who at that time projected that the Chinese effort in space would grow almost twice as fast as their economy and might even reach an astonishing \$25 billion/year level by 2025. (This forecast, as we will see, turned out to be premature.)

Progress in Japan

After 1985 the Japanese were judged by some investigators to be the most technically competent nation of all, especially after making allowances for their late start and lower GNP/capita (than the U.S.). However, their original goal of achieving parity with the U.S. in GNP/capita by 1985 was not achieved until 1992, and even then more because the U.S. growth had slowed to about a 2 percent rate--not because the Japanese were able to maintain their earlier momentum. Their economic growth

averaged 5 percent since 1975, which was high by world standards but only about half what they had achieved during the prior quarter century.

The Japanese were strongly (psychologically) affected during this period by the traditional poor mouthing of their resource situations. ("We are only a poor small country without our own energy or enough mineral resources of any kind," etc.) which they generally came to believe was critical despite hard evidence to the contrary--that is, that they were rich not poor and were getting richer rapidly. Feeling insecure prevented them from making substantial investments in a space program, the economic advantages of which were not at all clear to their principal decision makers.

Of course, there were many other relevant factors, not the least of which was the inroads made by the New Class concepts--especially after the middle '80s when the pressures by that ideology in the other OECD nations and from their own intellectuals came in many subtle ways to have an increasing impact on the Japanese. Without pressure from within their own culture or from their allies Japan's space program languished. It was to remain in a relative torpor until the commercial utility of space investments became evident worldwide--that change would occur only after 2025.

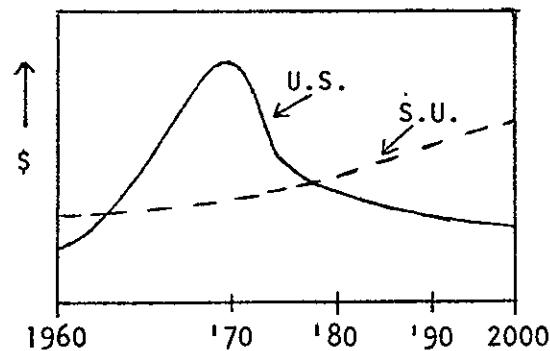
Space Program in Western Europe

The European Space Agency (ESA), whose principal contributors were West Germany, France, England, and Italy, struggled from its inception. Beset with problems of different languages, differing economic needs, and a bewildering array of public perceptions about its role or utility, it

was perhaps remarkable that ESA was successful in its \$.5 billion Space-lab project with NASA in 1980. Despite this success further attempts at a unified program proved to be too difficult in a period when science and technology were losing ground. ESA was abandoned in 1985 although each country maintained some kind of space program thereafter, but each of these continued to struggle. Only the West Germans managed a program whose growth kept pace with GNP but which nevertheless was unimpressive by American, let alone Soviet, standards.

Progress in the U.S.S.R.

Despite the Americans' spectacular early successes in space (the astonishing Apollo lunar landings, the miraculous Viking robots, the eminently successful Space Shuttle and Spacelab, as a few examples) the Soviet tortoise was to be well ahead of the American hare by century's end. This was the surprise-free result which was clearly signaled during the decade following the Apollo program by the graph of the U.S. space budget and its comparison to the (estimated) Soviet one which is schematically represented below.



Actually, both the Soviet economy and its space program grew slowly but steadily during the quarter at about a 2.5 percent rate. Nevertheless,

by century's end Soviet expenditures in space were estimated to be at least 3 times those of the U.S., and their advances in space science, space exploration, and in the potential for commercialization of space had become enormously impressive to specialists in space science and technology. Even though some of the ideology of the New Class had rubbed into the Soviet way of life and perhaps accounted for the slower growth rates in their economy and in space than would have been anticipated prior to the '80s, the change was relatively small. The simple fact was that without significant competition from the U.S. the Soviets became the Giants in space development well before the year 2000.

Beginning in the late '80s the American space buffs were to be subjected to a sequence of Soviet space "victories" that, because of their competitive attitudes, was to depress their morale. The Soviet Union was first with a:

- SSTO 100-ton payload unmanned reusable "freighter"
- Solar Electric Powered (SEP) orbital transfer vehicle
- Permanent lunar station (12 people)
- Lunar observatory and scientific laboratory
- Kilometer-sized space antenna
- Space industrial facility
- Solar Satellite Power System (SSPS--500 KW)
- Space station in geosynchronous orbit
- Nuclear space "tug"

The Soviet-American cooperation in space technology which had worked quite well during the '70s began to slip later that century as the "one-sidedness" of the arrangement became clear to both. By 1990 the arrangement had lapsed for all practical purposes other than desired voluntary disclosures. Although some people imputed military motives to the Soviets, this was later found out to be unimportant. The Soviet Union had simply preferred to keep its growing advantage over the Americans. The tortoise was finally enjoying its victory over the hare.

B. 2000-2025

Brazil

The Brazilian economy roared into the 21st century as the envy of the modern industrial world. It continued to average an 8 percent growth rate over the next 10 years, bringing its GNP to \$1.6 trillion. But after 2010, economic difficulties began to accrue which slowed Brazil's growth considerably. First, their largest oil and gas fields which were developed during the previous quarter had become substantially depleted, and the available profits decreased rapidly after 2010. This forced them into greater borrowing to finance much of their expansion goals--an option which soon brought severe limitations, and affected their economy over the balance of the quarter. Furthermore, their growing foreign exchange problems after 2010 stopped and then reversed somewhat the flow of external (and expensive) brain power toward Brazil--unfortunately before their internal advances in education were sufficient to produce the required indigenous competence needed to assume the tasks performed by the foreign talent.

Their booming space program which by 2010 had a budget of over \$3 billion, "the largest in the free world,"--as the Brazilians were not slow to proclaim--was affected by the growing economic stress after 2010 and, although it continued to increase, the growth after 2010 averaged only about 3-1/2 percent for the last 15 years, ending with a respectable, although not spectacular, budget of \$5 billion. From the beginning their program had a dual purpose: to help develop Brazil's science and technology capability and then to enhance their economic development by exploiting space industrialization as well as the abundant spinoffs and the utility of earth-oriented satellites. Later, in 2017, they promoted

the world's first serious commercial space tourist enterprise. Both the space industrialization and the tourism ended the quarter much less successful than the Brazilians' earlier expectations.

The principal problem in their space industrialization effort was that its commercial success depended to a large degree upon their ability to export its innovative products. But in their enthusiasm they had, too naively perhaps, refused to understand the depth of the resistance in the developed (and now post-industrial) world to innovations in technology--especially from abroad. Thus, although a flood of new and, to them, exciting products and processes emanated from that program, foreign consumers did not eagerly run to Brazil to buy these products and services. The slow acceptance and long procedural delays made the commercial aspects of the program very awkward since the economies of scale needed for efficient production often required very expensive large-volume space installations. This resulted in a number of costly abandonments during the quarter--and a number of broken dreams.

The space tourist industry was formally started in Brazil in 2017. The cost for a week's tour in NEO started at about \$50,000. Business was brisk for about five years and then flattened out just as a greatly expanded capability was being installed. Supporters of the New Class condemned such costly, "gaudy" expenditures as inconsistent with their ideology--a view which after the exciting first few years increasingly restricted the available volume of foreign business. However, a careful study revealed that the most significant factor was that about 10 percent of the lay space travelers were significantly discomforted by the physical stresses associated with the transition to weightlessness and subsequent

reentry and adjustments. This led to a rather bad press and tended to discourage the interest of would-be space tourists. Indeed, the Brazilian authorities had been all too casual in their attitude towards the physiological aspects of this new venture. They had decided to treat it as a strictly commercial venture--a decision which in effect left the establishment of criteria for space traveler selection and preparation in private hands. Unfortunately, the franchised operating corporation in its enthusiasm (or perhaps from financial pressures) was less than completely careful in its approach to the physiological considerations. By the end of the quarter the industry's capacity (50,000 tourists/year) was more than twice the demand for seats. Some huge losses resulted that were to make future investors quite wary of commercial ventures in space.

U.S.S.R.

The Soviets entered this quarter as the space giants by virtue of a budget estimated at about \$7 billion for non-military development. Their space industrialization effort was directed toward furnishing new products and processes for Soviet industry. Even though they created many which were interesting, even exciting, they made a mistake (common to many new Soviet commercial ventures) by overestimating the ability of their traditional industries to respond to innovation. The sluggishness of routine Soviet commerce was usually only experienced directly by someone who tried to encourage change. Except in the production of new scientific or military equipment (and not always then) the resistance of the Soviet system to the acceptance of innovation was profound. In a Soviet factory such change generally meant little but trouble to the commissar of production, making him loath to give up a satisfactory routine for

something new--especially when failure usually brought great punishment and success, small rewards. Thus, the Soviet space industrialization effort--like that of the Brazilians, but for different reasons--had a severe marketing problem which greatly impeded its potential development.

Their science and exploration program, however, was excellent and they easily maintained their lead in these fields for the quarter. The Soviet space budget grew during the quarter but the average rate of growth rarely exceeded the "standard" 2.5 percent. By the end of the quarter their budget was estimated to be \$13 billion, about double that of the Chinese who had made significant progress and had the second largest effort. Their lesser efficiency, however, reduced their budget advantage considerably.

China

The economic progress made in China was steady if not spectacular. The Chinese maintained a well-balanced growing space effort suited to their own needs. Their orientation emphasized both basic science and applied research and technology. In addition to their earth-oriented satellite program, they concentrated on developing spinoffs for their potential utilitarian purposes. Their interaction with the space programs of other nations was kept relatively small although they were present at every international conference which related to space developments. At these gatherings their contributions, while few, soon acquired a reputation for unusually high quality.

During this quarter their space budget--keeping pace with their GNP--grew at an average of 5 percent annually. By 2025 it exceeded \$7 billion. The effectiveness of their effort was clear to all space

scientists--some of whom stated that China's program shone with a quiet brilliance that often was not observed because of the minimal communication and lack of publicity beyond their borders. But by the end of the quarter Chinese presence was observed almost everywhere in space where other countries had been successful. The Chinese Space Transportation System was well balanced and efficient. Their array of space tugs included nuclear propulsion systems as well as ion engines, solar sails, metallic hydrogen thrusters, and beamed energy systems. They had a small 6-man Mars station and were studying the asteroids with both manned and unmanned vehicles. Their contributions to space astronomy during the quarter had on several occasions startled the scientific world with new findings (for example, the first reliable description of the distribution of black holes in the galaxy by type, size, and density--i.e., number per cubic parsec).

Japan

During this quarter Japan was the richest country in terms of GNP/capita and turned largely into a consumer-oriented society--but with growing elegance. The lack of international commercial interest in space industrialization (except COMSATS and other earth-oriented satellites) was apparent to them, and they were content to participate in the scientific and exploratory aspects in cooperation with the Americans, the Brazilians and others. Being the richest they were more eager to maintain their position than to attempt to further outrun others. They constituted a rather large fraction of the space tourists who patronized the Brazilian system and appeared to be less disturbed than others by the weightlessness problems.

The New Class ideology, however, increasingly affected them and the demands for sharing more of their wealth with the poor (Fourth World) were strong, both from within their culture and from the outside. The internal ideological conflicts combined with some of their growing altruistic motivations to reduce their former growth capabilities which slowed to 3 percent by the end of the quarter (averaging 4 percent). Still their per capita GNP reached \$30,000.

U.S.

The U.S. had been in a prolonged depression (since about 1985) which had been justified as the price of an improved QOL. But by 2015 the QOL concept was not much more clear than it was in 1976. The social conflicts between the productive and unproductive segments of U.S. society remained severe. The U.S. was considered to be the world leader in very few areas of former importance and had lost much of its earlier competence in organizing and managing industry and in applied innovations. Its scientific group was competent--but relatively small and isolated--and tended to emphasize theory more than experiment because of meager funding. It was also becoming clear that the New Class was becoming an "old class" and that its ideological grip was starting to fade. It was not clear what direction(s) the country would take as the quarter ended, but there was a sense of imminent change.

The space program by 2025 had dwindled to the point where it was maintained at about \$1 billion annually, with more than that (about \$2 billion) being invested by private industry which had taken over most of the commercial earth-oriented ventures, COMSATS, LANDSATs, SEASATs, etc.,

and the small SI program which was developing only very slowly as an advanced transportation system (mostly constructed by the Brazilians) was just being phased in on a joint venture basis (involving Brazil, West Germany, Japan, and the U.S. government as well as private industry from each country).

Europe

The New Class ideology continued to prevail in Europe. The costs of providing pure clean energy, achieving and maintaining environmental purity, and providing welfare assistance in and out of the country had severely drained their resources--especially as interest in new technology had weakened as well. The Germans held a stronger technological interest in space than the other European countries but it was difficult to maintain even though it was not large. Economic growth in Europe averaged about 2 percent during the quarter; about half of that was given away in foreign aid. Fortunately for Europe the Soviet Union did not have a military appetite during that period.

C. 2025-2076

China

Strangely, perhaps, the quiet but pervasive Chinese confidence in their "inherently superior" culture may have been the most important factor in developing an ideology which led to their preeminence in science and technology--and in space development in particular--during this period. In retrospect, it appears that the Chinese probably had been more egalitarian, in a national context, than the countries which had adopted the New Class ideology--which in most countries often was only accepted in a casual or surface manner, like that of the Sunday morning Christian. However, the Chinese had learned to couple their "egalitarian" economic distribution system with a productive one which emphasized excellence and which had always included environmental protection as part of the system--well before the U.S., for example, passed its first National Environmental Policy Act (1969). The need for an appropriate balance between cleanliness, in the larger sense, and production was more ingrained in the Chinese than in the other countries and consequently made it easier to resolve new conflicts as they arose.

Economic growth, per se, was not an overriding motive in China as it had been in most of the free world. Rather they had emphasized an unheralded underlying admiration for wisdom, competence, and excellence in all of its forms. Wealth was a great potential aid to the achievement of progress in this context but wealth, in itself, was not admired as a measure of success. Moreover, their communist system did not permit much wealth to be accumulated by individuals, thereby effectively removing it

as a personal goal. But general increasing wealth for the country--also in reasonable proportion for the smaller regions, and for local communes or industries--was more expected than desired. Of course, the battle for funding was always a struggle and in retrospect could always be found to have been suboptimal. But the sustained common goal was that of promoting the greatness of the Chinese culture through progress in every important attainable way: arts, science, technology, education, health, sports, etc.

The Chinese GNP grew steadily--usually about 6 percent annually in real terms--as best this can be measured. By the year 2050 they were rich in a world sense having passed all of the OECD nations, except Japan, in GNP/capita. But with 950 million people their GNP came to almost \$20 trillion that year.

The big surprise however was their space budget which, increasing at an average rate of 10 percent from 2025, reached \$75 billion in 2050. By that date the Chinese had become the outstanding world leaders, not only in space technology but in science and technology, quite generally. Moreover, it had become clear that it was unlikely that any other country would or could surpass them in the foreseeable future. Their wealth, population, GNP, scientific establishment, technological competence, and, most of all, momentum made effective national competition unlikely for the foreseeable future.

Competition, however, was no longer a key issue. By mid-century the Chinese culture had evolved to the point where it was quite secure, where its national boundaries were deemed to be more the result of an historical set of accidents than the 20th century view of a cause celebre over each

debatable line. Since 2025 their culture had opened up a relatively free exchange with the rest of the world. The results were slow in coming but they were predictable. China had become a successful model for the developing and the developed countries as well. Naturally, there was an attempt to follow that model as best it could be perceived and understood. But, of course, it was difficult. Societies rarely change rapidly in foreseen ways. Attempted change, whether planned or evolutionary, is generally resisted, and is usually misunderstood. However, the Chinese model was there and the communication system available almost everywhere in the world made the detailed operation of this model easily accessible, if not always easy to comprehend.

Several important international developments had occurred or began to occur after 2025. First, it became clearly understood, worldwide, that poverty in any form was a sign of deep social sickness within the society of which it was a part. Moreover, there was always an escape route available in principle. The wealthy countries of the world--especially China and Japan--were ready to assist any country or culture in which the desire to eliminate poverty was believed to be genuine. This attitude had always existed on a small scale but by the year 2050 it had become a large scale standing commitment to any society in which such a result could reasonably be achieved without a military intervention.

Indeed, military solutions had become less and less important over time. After 2050 they essentially disappeared. There were several principal reasons. First, Japan had clearly demonstrated that land was an increasingly small fraction of a nation's wealth and therefore relatively unimportant for economic reasons. Second, and perhaps more significant,

was the capability, fully developed shortly before the year 2010, to detect and prevent any child from being born with serious genetic defects--including those which would seriously impair mental or emotional functions. Although application of this technology was slow for a decade or more, by 2050 it was very rare for any child to be born with any such handicap. Thus, the concept of a clean environment had been extended to include genetic "cleanliness" and it helped to stabilize societies.

Another reason for the fading interest in military solutions was the lack of interest among the leading great powers: China, Russia, Brazil, Japan, U.S.A., West Germany, Mexico. China had even startled the political world in the year 2028 by renouncing any formal claims to Taiwan--and at a time when the Island could probably have been taken readily. The surprising result since then has been a rapid gravitation of the Taiwanese toward China and a surprising amount of reunification sentiment in Taiwan--a possibility that China was no longer eager for, primarily because of the cultural disparities which arose out of the long separation.

Thus, the stage was set in 2050 for a slow cultural change in the world towards the Chinese model--which was itself evolving. The next 25 years was to witness the world's most immense change, one which led to the society we have today. The notion inherent within egocentric cultures that a democratic society should be oriented to maximize the individual's QOL and his personal goals wherever they may lead was eventually deemed to be inadequate because of its inherent tendency towards internal conflict, fragmentation, or even anarchy. A basic conflict arises from its inherent encouragement of freeloaders, who over time may approach or become a

majority and through their political influence (in a democratic political system) tended to place an unacceptable load upon the rest of the society. Some of the countries which had been dominated by the New Class ideology began to shake it off before mid-century. After that point in time the trend accelerated. Now, in 2076, the New Class has become history; the theme of the U.S. Tricentennial celebration is Rapid Progress, through Knowledge and Wisdom.

The total world effort in space development this year will be about \$1.2 trillion; \$500 billion will come from China's space budget, \$300 billion from reinvested space production (2/3 Chinese) and \$400 billion from private investment and the budgets of other countries of the world. Perhaps the most important current development is the new sense of harmony in world science and technology, indeed in the world's interest in knowledge, in cooperation, and in establishing new goals for mankind. The successful Chinese space colonies at L-4 and L-5, and on the moon, and the recent large international scientific laboratory on Mars, coupled with the impressive, rapidly growing space industries, have given a new vision to mankind about his potential future. This was greatly aided by the Chinese space tourism program.

This tourism program was started in 2030, shortly after the Brazilian program became stagnant. The first Chinese tourists were selected from the list of qualified interested applicants by lottery. Since that time it has grown rapidly and a modified lottery system is still being used. After 2040 selected foreigners were welcome to use the Chinese space tour system which is now the world's largest by far. The growth of the system is shown in the table below.

Table 18

CHINESE SPACE TOURIST PROGRAM

TOURISTS (THOUSANDS)			
<u>DATE</u>	<u>CHINESE</u>	<u>FOREIGN</u>	<u>TOTAL</u>
2040	20	1	21
2050	250	50	300
2060	3,000	1,500	4,500
2075	22,000	10,000	32,000

Not only have the numbers of tourists grown rapidly but the duration and nature of the tours have changed. The average tour today is 30 days, compared to 7 in 2040, and the itinerary generally includes a week on the moon and a visit to at least one of the space industrial installations--in addition to the special NEO facilities for tourists (hotels, hospitals, museums)--and to a colony at L-4 or L-5. However, the cost, at \$23,000, is a little less.

Brazil

Early this century the course of history appeared to have given the Brazilians a unique opportunity to have become the world's model for successful development. However, the model which shone brilliantly for about 40 years was not soundly enough based to maintain its momentum. Of course, the Brazilians did extraordinarily well during that period and became one of the world's most advanced countries--in several senses perhaps the most advanced for a short while. One of their problems, their requirement for income from natural resources, had not ended when the more profitable resources did and forced them once again into heavy borrowing in an attempt to maintain their growth. Secondly, they were locked into an international

economic system that was stagnant or at best growing very weakly, which created various kinds of resistance to their growth potential. Finally, the 40 years between 1975 and 2015 that they had had to become independent of external assistance, were simply insufficient for the required social changes to occur, the ones that were needed to invigorate the entire population. Those would require 75-100 years, depending upon various external and internal factors.

The Brazilian culture was basically oriented toward economic growth and employed technology and capital as its principal means of achieving that goal. Their initial successful gambles to develop economically on borrowed funds, their successful efforts to exploit natural resources for additional capital, and their bold program to import both the technology and the technologists gave them a tremendous boost, but it was insufficient as a self-sustaining arrangement. When the principal exportable resources were largely used up, when borrowing had reached practical limits and their conversion to a modern industrial society was incomplete, they had to endure a long period of adjustment from about 2015 to 2050, during which their economic growth became relatively low (and, of course, their technological development programs in space as well as on earth became relatively flat).

Their fine space effort which reached \$3 billion annually at 2010 and far exceeded the American budget, at that time constituted the principal hope for the development of space among the non-communist countries. However, this budget grew only to about \$5 billion during the next 15 years. These sums were sufficient for a variety of developments including

an advanced Space Transportation System, an early Space Industrial effort and a very respectable science and exploration program which included a lunar colony, an advanced modular space base, and a manned geosynchronous space station.

However, the growth of the program after 2010 was primarily dependent upon the successful commercialization of space. This failed in part because the tourist program was not very successful, as discussed earlier, and because the space industrialization program required the support of a vigorously growing world interest in new technology. Unfortunately for Brazil during those years most of the developed world remained in an ideological state which resisted innovations in technology and thus hampered its commercial space effort.

Therefore, it was not until the middle '30s when the Chinese model began to affect other nations significantly, including Brazil, and opportunities for growth again appeared, that the situation began to change. By 2050 the Brazilian economy was booming; their space budget reached \$10 billion and was growing rapidly. During the following quarter it averaged a 6 percent growth and reached \$40 billion only last year. Also, neither Brazil's economy nor space program is now dependent on outside assistance, in the sense that it was at the turn of the century. Of course, the world is also much more cooperative now and national commitments to the world space program appear likely soon to become "standardized" as the program becomes more international or, as some expect, supranational.

U.S.

Since this is our Tricentennial year we are at once pleased at the recent rapid progress and the renewed commitment to space development by

the U.S., and--looking back--are surprised at the astonishing pause in activity that U.S. and other countries experienced for about 75 years. Perhaps something valuable was gained through this experience--perhaps it had to happen to prevent a truly disastrous outcome. That is an unknowable and wishful statement at present, but maybe it can be analyzed in coming decades. We have learned a great deal about societal trends, social forces, and human behavior during the last century, and perhaps we will be able to solve these harder problems before long. While we all are grateful to the Chinese for having helped to pull us out of a profound slump, it is clear that it would have occurred eventually by other means. The Chinese themselves were the first to make that point clear. But sooner is better than later. To have "lost" another 50 years in the "doldrums" would have been unfortunate for billions of people.

THE NEW INTERNATIONAL ORDERS

PART II: THE TRIUMPH OF THE GARDEN?^{*} (2025-2075) (A WORLDWIDE PESSIMISTIC SPACE DEVELOPMENT SCENARIO)

From the viewpoint of the world's space buffs the first quarter of the 21st century was a relative 'disaster.' Except for the flashy effort in Brazil which was somewhat in disarray at the end of the quarter and the steady progress in China, there was little for them to celebrate in the rest of the world. Indeed, most of the world seemed to be turning inward rather than outward. Science, technology and industry were primarily being harnessed to fulfill the perceived material and environmental needs and to make the world a safe place in which people could devote themselves to traditional artistic, cultural, social, and political pursuits.

The potential rewards of space development and space travel had been debated by the New Class and found wanting--indeed had been judged to be too costly and relatively risky, especially where it involved manned programs. Moreover, there appeared more and more philosophical, religious polemics that asserted that man's attempt to scatter his seeds even further into space was an incipient new form of pollution, if not desecration, of the purity and beauty of the universe. The orbiting weapons in space, the threat of pollution or other permanent damage to the upper atmosphere, the potential for space warfare, and the inevitable accidents which resulted in space debris and occasional deaths were all cited as evidence of the evil potential of unfettered development attempting to slip out

^{*} This is a variation of the previous scenario after the year 2025. Its first 50 years are identical with pp. 173-192.

from beyond the new controls of reason which had only recently been won on earth.

The unfortunate experiences of the Brazilian space tourism venture furnished extra fuel for the arguments against space development. The tendency of the human body to adapt to new environments had created stresses among many of the tourists that had unpleasant, if temporary, physical consequences with symptoms of vertigo, dizziness, palpitations, weakness, headaches, and high blood pressure. Some of these symptoms were believed to be amplified by accompanying anxieties--especially when real or fictional stories about prior space-related disturbances were discussed or recalled. Naturally, the worst of these experiences were those which received the most publicity and distorted the public's ability to make accurate judgments.

Brazil

The bankruptcy of the first Brazilian space tourist venture had a profound effect upon many other commercial aspects of their space program. Capital became hard to come by since the risks were believed to be high and the government was no longer willing to subsidize private ventures. Indeed, because of its own losses in space industrialization ventures and with a struggling economy that had developed huge debts, the Brazilian space program was severely slashed during the 2025-2035 decade and eroded slowly after that. By 2050 its funding had fallen to a \$2-billion level and it had essentially become an "orphan" agency in the government--one of low prestige and in a no-growth maintenance mode.

Brazil's troubles in space were part of its prolonged economic difficulties that had begun about 2020. The need for new capital after 2030 became more pressing as available funds were drying up. Brazil's ability

to entice foreign experts had ended and the previous in-flow became an outward one. The foreign scientists and technologists attached to space projects were among the first to be phased out--and the trend was quite clear. All foreign technological personnel whose economic security in Brazil was threatened faced a very uncertain future since they generally had to return to home countries in which their kind of expertise was already in surplus. Of course, there was no real threat of poverty or disgrace--the developed societies were quite beyond that--but for most of these returning experts their careers, status, identities, and morale were to require a substantial period of adjustment.

The flamboyant confidence that formerly characterized that giant country, which for decades had been the envy of the developing world, disappeared during the '30s. Still the people had attained a relatively high standard of living. The GNP/capita was \$11,000 in 2025 and has during the last 50 years slowly increased to about \$18,000. Their lack of economic dynamism has been replaced by a greater concern for equity, justice, social welfare, and other requirements for a high QOL which had been relatively neglected during the heady growth stage. Thus Brazil is now considered to be a mature post-industrial society without the restless driving ambitions that characterized its "adolescence" during and shortly after the 20th century.

China

During the first quarter of this century the Chinese economic growth rate had started at 6 percent but then slowed to 4 percent (averaging 5 percent) and in 2025 their GNP reached a respectable \$5.4 trillion, or

about \$5,000/capita. As they approached this level despite the government planners' efforts to make a harmonious transition into a modern superindustrial society--which earlier had appeared to be feasible--the changes in Chinese society had become so rapid and so complex that their struggle to avoid the pains of successful growth became increasingly frantic. Their need for capital was immense but they were traditionally aloof from borrowing. Their determination to avoid indebtedness, while admirable, had become impractical. They had used up their inexpensive indigenous energy sources and needed to invest about \$5-trillion just to phase into the long-term inexhaustible sources over the coming decades. Moreover, they avoided buying technology developed abroad but, as usual, insisted on developing their own. This fierce international independence was a luxury which was to increase their troubles. Perhaps most important, however, were the emerging QOL issues.

During the preceding quarter the restlessness of the younger Chinese had started to have an increasing influence on their society. Improving communication systems had brought them into indirect intimate contact with the world's many diverse cultures and the younger people were discovering and expressing a need for more direct interaction. They began to resent the feeling of being constrained within their own relatively severe culture--one bent upon national progress, outstanding excellence in performance and cultural greatness, all of which implied a life of dedicated hard work toward conceptual goals that after the early '30s no longer satisfied most of the younger generation. The dissidents' view of the external cultures and especially of the New Class ideology--which to them implied a much improved QOL now, rather than a continued struggle

toward hypothetical future gratification--was simply that it was vastly preferable to their own constrained and difficult routines.

The youth "rebellion" received increasing support from many of the adults who had also become somewhat unsatisfied with their lives. Television or holovision "travel" generally was not considered an adequate substitute for the reality experience. Listening to music or watching dramas was a poor substitute for performing in these arts. Or more generally the concept of finding and doing your own thing, rather than fitting into the nation's plan, rapidly became an appealing lure, once the new youth subculture became influential.

Naturally the entrenched authorities resisted, but insufficiently; they tended strongly to believe the traditional notion that "it can't happen here" or that the perceived trend would soon reverse itself--while they watched it grow and become dominant. The main part of the struggle, during the period 2030-2050, was generally non-violent; but the outcome was clear before mid-century. The New Class ideology had effectively penetrated the culture, without direct proselytizing, and over the 20-30 year period had won the political battle. With the "fall" of China into the appeal of the foreign cultures there was no longer a nation which could champion the more difficult route emphasizing wisdom and excellence in every important endeavor. Evidently economic success which led to a post-industrial society sooner or later was destined to yield to the temptations of a mode of life with more personal short-term fulfillment. At least this outcome had occurred in nearly every economically successful country in the world. The Chinese culture had been the last real hope for providing to an otherwise stagnant world a dynamic

technological and economic model with a far reaching vision of human destiny.

During this last quarter (2050-2075) China's economic growth was almost nil after having averaged 2 percent during the previous one. Their recent R&D budgets for most science and technology, including space development, have been shrinking. However, at \$10,000 per capita the population is free of poverty, their health is good, and they devote themselves to work-play or play-work much as in the Western world. Their political wrangling, of course, has been furious as it is almost everywhere, as governments under pressure from innumerable factions struggle to improve the elusive QOL for their citizens. The Chinese technologists and scientists have lost their former elevated status but still keep the productive part of society going by developing or maintaining the automated systems upon which the country's material well-being depended. Compared to the conditions of a century ago it appears to be a very good life for most of the people. For those who remember and long for a world of continuing progress, wisdom, and outstanding performance in all fields of endeavor--and, as one of its principal manifestations, for the ascendance of the Chinese people into the farflung reaches of space--for them the current world is a shallow one spinning slowly, endlessly, round and round but with little hope of making their great dreams come true.

The Perpetual Garden

So many forecasts of the future had been made in the late 20th century that almost any outcome would have had at least one prophet. As a post-industrial society develops, the tendency of most people to lose interest in advancing technology and economic growth had long been noticed and frequently discussed. Indeed, it had become one of the primary 20th century images of the future--probably because it had already started to happen in the wealthier nations. Thus, a major surprise-free prediction of that time--reflected in the wealthier nations by the New Class ideology--became a kind of self-fulfilling prophecy. But it became even more than that--in the sense that the attraction of the concept also spread to the other countries of the world, once they had developed their economies sufficiently.

Whether or not the outcome was inevitable, advanced technology was used to promote it. Every major accident that occurred during the last quarter of the 20th century and subsequently, that could help promote the spread of New Class ideology, employed modern advanced communications to bring the details to the attention of the public. Over the course of the next fifty years some real horrors occurred that helped greatly in fostering the influence of this ideology. For example, any trouble with nuclear power plants became instant headline news after 1970. When the first really major accident occurred in 1987, in a "runaway" reactor near Los Angeles that enveloped a substantial portion of that huge city with a radioactive cloud, the ensuing panic as people struggled to rush out of the city only ensnared the flow of traffic, adding automotive exhausts to the troubled city. Unfortunately the accidental release of radioactivity was coupled with an atmospheric temperature inversion and

other meteorological conditions which prevented an early dissipation of the radioactive cloud. In retrospect the radioactivity was much less of a threat than the panic--but this could not be communicated to the residents in time. As a result a million people were stranded far from their homes in huge traffic jams and, because of changing winds, often had driven into, rather than away from, the areas of greatest exposure. The public fury which resulted stayed at an intense level for weeks while the grim details were continually flashed to the world by satellite television, in color.

The following year a liquified natural gas tanker ran aground off Cape Cod; the subsequent fire caused 500 deaths, 15,000 serious injuries and more than \$10 million in property losses. This was followed in "rapid" order, in 1988, first, by the explosion of a chlorine plant in Yokohama, and then a tragedy in space when, after the first landing of a telescope on the moon, the returning spacecraft with six astronauts aborted, a few seconds after launch, killing the occupants. This occurred on the far side of the moon; however, the tragedy was brought into full view by television pictures relayed from the Lunar Orbiter.

The "small" nuclear war of 1995 between Pakistan and India involved "only" three kiloton-size weapons--but 150,000 deaths and a million severe injuries resulted. The prior war between North and South Korea, in 1993, was non-nuclear but longer and almost as grisly, as civilians bore the brunt of the casualties because of indiscriminate attacks on population and industry. At that time advanced space satellites both photographed and transmitted these grim events around the world. "Technology" was blamed by the New Class for making possible each major tragedy.

The list goes on at great length. The essence of this 50-year sequence of tragedies is now preserved in the famous 46-hour video program entitled Lest We Forget. This program is a mandatory part of the present education of every child in the post-industrial nations.

There are some "radical" intellectuals who claim that the emphasis on tragic aspects of technology distorts the "true" picture--meaning that the benefits are improperly weighed. This argument has not gathered many adherents--except among dedicated technologists--and tends to become weaker over time. The people prefer their lives to be free of the risks of wars, radioactive contamination, explosions in mines and factories, cancerous chemicals, and threats to the fragile envelope of air that must protect us daily--to name but a few of the many dangers from indiscriminate technology, and the lust for ever-increasing personal wealth.

The tendency in the U.S. today, indeed in most of the world, is to resist any potentially dangerous new technology--or the impact of the uncontrolled "Machine," as the technological subculture is popularly referred to. In the most important sense this is the democratic process. By the vote of the vast majority, the Machine is to be maintained and carefully nurtured, but it must be kept subservient to the desires of society. For the past 50 years at least, the understanding of science and technology, the basis for the Machine, has required fewer and fewer people, although this is not a trend towards zero. Over these years the technological sectors steadily lost status (that is, political influence) as their active population shrank. Although the ownership and control of industry and R&D establishments are largely distributed among the general population or within the government, the knowledge required to maintain or improve technology is now concentrated in the small Machine subculture.

Some of our sociologists are concerned about this development since a number of ominous scenarios of the future are thought to be possible, if unlikely. For example, suppose for society's stability the number of people operating the Machine was required to exceed a certain minimum--that is, to prevent the possibility of a relatively sudden collapse. How can it be assured that this critical point is not reached--especially since social power and prestige are generally associated with the other professions such as Law, Politics, Finance, Publicity, Artistic Performance, Sports, and Management? That is, the argument goes, the QOL in society more and more has become dependent on the Machine while, in a social sense, it increasingly disdains or ignores its professionals.

The U.S. space program is now dependent upon a mere 10,000 individuals who alone have the technical training to keep it functioning. Tours in space have recently become relatively popular again and a growth trend in this activity will continue as long as the Machine personnel can maintain it adequately. After formal schooling and apprenticeship, each of these individuals will be required, over time, to complete at least 10 years of additional study and training to remain a qualified professional. During this period he will be expected to work to maintain society's Garden, without, in a spiritual sense, being a part of it. The sociologists warn us to keep a careful watch that this separation of society into two subcultures remains sufficiently satisfactory to both parts.

A similar situation, of course, exists in all post-industrial nations, and appears to be relatively stable everywhere. Although some sociologists continue to worry about it, most other people are too busy to be much concerned. Indeed, the very long-term outcome may be beyond analysis in any reasonable sense. The general prevailing attitude is that the technologis-

are content with their robots, lasers, computers, and rockets, and there is no reason why this should change.

However, the division between the technological and non-technological cultures has grown very sharply during this century. It is almost as if two alien cultures have managed to live under the same government while one of them shrinks slowly over time yet becomes increasingly vital to the other. The majority is not, at least in principle, vital to the minority--except in the sense that they hold the current political and financial controls.

Now that China, Brazil, and many of the other former "Third World" nations have become post-industrial, the remaining fourth of the world's population--principally in South Asia and mid-Africa--that are still in the earlier stages of industrialization are being helped in their upward struggle so they too may become post-industrialized. Actually this process appears to be proceeding steadily and estimates indicate that in the latter part of the next century this outcome may be quite general the world over.

Growth in economic output has been very slow recently, when it occurs at all. Energy and material consumption in the "Garden" countries has been almost flat for the last two decades. The continuing development of automation in industry is about balanced by the growth in government and private services. To some extent the computation of real GNP is somewhat of an "artform," since the changes accumulated over time make it hard to make meaningful comparisons with prior decades; at least many leading economists have been making this argument for a long time. However, the important measure to society is their

quality of life. Of course this has to be partially subjective, but the general consensus is that it is gradually improving.

Some of the technologists operating the Machine--the space development enthusiasts in the U.S., for example--have expressed frustration at what they believe is an excessive constraint on funds for projects they would prefer. However, society can ill afford to "lose" many of these highly trained people to the pursuit of expensive projects which may have little social benefit, and possibly some important disutilities--especially as each of them usually has a substantial area of responsibility that must be maintained for the benefit of society in general. The restlessness or frustration among the technologists has been chronic for some time but has not measurably worsened, according to government subsidized studies, and therefore is not expected to pose a substantial threat to society's stability. Thus, our society, or our Garden, to use the popular term, appears to have considerable survival value for the long-term future. The people are busy, generally content with the present arrangement and do not wish to risk their QOL by supporting new developmental activities which have even a small potential for disruption. Why should they? This Garden is theirs! They expect it to last for a very long time--and to be enjoyed by their children's children's children's...children.

Chapter VI

A MODERATE SCENARIO

PART I: SOME GOVERNMENT PERSPECTIVES

A. 1976-2000

Social Attitudes Toward Growth

Almost everyone has experienced the feeling that social changes are very slow. This feeling generally comes to those who desire certain changes and are waiting for them to occur. Thus, in the great depression of the 1930s the way out seemed that it would never come. The energy crisis of the 1970s and '80s seemed like it might never end, etc. But this appearance of slow change is an illusion. Since the industrial revolution began no person from an industrialized country has experienced a period of 20 years without profound social changes occurring.

In this sense the developed countries of the world during and shortly after 1975 found themselves in the grip of an economic slowdown, a constant pressure toward inflation, a conflict between rising pressure groups that believed in limiting economic growth and traditional growth-oriented citizens, and an ongoing ideological conflict between centrally-controlled and market-controlled economies. Although the world was to change radically, in many ways the above features were to be surprisingly persistent and would lead to rather agonized or agonizing cultures. So much time was spent trying to resolve conflicts that refused to yield much--although new areas of conflict had little difficulty in arising--that a sense of being trapped in one's own making became increasingly widespread and for several decades had a depressing effect upon public morale in most countries.

Despite these socio-political difficulties economic growth did occur at roughly historical rates for the last quarter of the 20th century. This was probably due in large measure to the phenomenal "explosion" in science and technology, in which a growing effectiveness was occurring even while much of the public's attitudes toward them reflected the neo-Malthusian orientation of the New Class, and R&D budgets were under perennial stresses. The "explosion" could occur in such circumstances primarily because the "electronic revolution" permitted scientists and technologists to perform more with less time and money; this more than compensated for the stiffening opposition.

The U.S. space program was a case in point. Although the U.S. space budget increased in real terms after 1980, the average increase was less than the GNP growth, and always far from satisfactory from NASA's point of view, and a source of bitterness to space enthusiasts each of whom longed to see his favorite projects funded--usually in vain. Nevertheless, in reviewing the developments in space over the quarter century the U.S. program achieved some remarkable results (see Table 19).

During this quarter it became clear that the world population would soon stabilize and probably would not exceed 10 billion. The most useful technological assist to this expected outcome was the simple procedure for reversible sterilization that could be applied to either sex, and which for women became insurable at \$1 per year, with a \$100,000 benefit for any resulting pregnancy. The two developers of this technique were awarded the Nobel Prize in Medicine for their valuable contribution to the long-term welfare of humanity.

Table 19

HIGHLIGHTS OF U.S. SPACE ACCOMPLISHMENTS, 1976-2000

1. THE EARTH-ORIENTED SATELLITE PROGRAM WAS A REMARKABLE SUCCESS. IT TOOK OVER ESSENTIALLY ALL NAVIGATION, COMMUNICATION, MAPPING, EARTHQUAKE AND STORM WARNINGS, CROP AND WATER INVENTORIES, BECAME AN INDISPENSABLE AID TO EXPLORATION, AND OFFERED CONSTANTLY IMPROVING WEATHER PREDICTIONS.
2. THE SPACE TRANSPORTATION SYSTEM DEVELOPED THE SHUTTLE AND LATER THE IMPROVED AUTOMATED (UNMANNED) SHUTTLE TOGETHER WITH A COMPLEMENT OF SPACE TUGS AND PLANETARY LANDERS FOR THE MOON AND MARS. BY CENTURY'S END THE COST OF LAUNCHES TO NEAR-EARTH ORBIT HAD DECREASED TO \$80/LB FOR FREIGHT AND \$150/LB FOR HUMAN PASSENGERS.
3. THE DEVELOPMENT OF A PROTOTYPE SPACE INDUSTRY HAD REACHED THE POINT WHERE A DOZEN PRODUCTS HAD BECOME COMMERCIAL AND MANY OTHERS WERE DEPENDENT UPON THE NEXT GENERATION TRANSPORTATION SYSTEM. MEANWHILE THE R&D FOR NEW PRODUCTS AND PROCESSES HAD ABOUT A \$100 MILLION ANNUAL U.S. FUNDING (1/2 FROM INDUSTRY) PLUS A ROUGHLY EQUAL AMOUNT FROM EUROPE AND JAPAN.
4. THE SCIENCE AND EXPLORATION PROGRAM BECAME A SERIES OF SPECTACULAR DEVELOPMENTS. THE SPACE TELESCOPES AND OTHER SENSORS REVOLUTIONIZED ASTRONOMY AND COSMOLOGY. THE TWO MARTIAN ROVERS FOUND EVIDENCE FOR RUDIMENTARY LIFE FORMS ON MARS. THE LUNAR STATION NOT ONLY DISCOVERED WATER BUT VERIFIED THE FEASIBILITY OF MINING FOR USEFUL MINERALS AND MADE PLANS TO BUILD THE FIRST SMALL-SCALE ELECTROMAGNETIC ACCELERATOR.
5. THE FEASIBILITY OF A MANNED GSO STATION WAS ESTABLISHED AS WELL AS THE MAINTENANCE OF LARGE GSO ANTENNAS AND SOLAR POWER SYSTEMS.
6. SPACECRAFT WERE SENT TO MAKE CLOSE-UP OBSERVATIONS OF ASTEROIDS AND COMETS--DEMONSTRATING THE POTENTIAL OF THE ASTEROIDS FOR MINERALS AND OF THE COMETS AS A HYDROGEN SOURCE.

Economic progress during the quarter was steady if not spectacular, with Brazil emerging as the outstanding developing nation with an average annual growth rate of 8 percent. Of course, the OPEC countries did remarkably well--although after 1990, when oil prices started to drop, many of them experienced economic difficulties. With the exception of south Asia and middle Africa, the developing nations grew about 50 percent faster on average than the developed nations. These results are indicated in Figure 2, p. 62.

Military Systems in Space

One of the more disheartening failures during the '90s was the lack of any meaningful progress towards arms control, conflict resolution, or effective international restraints against war. In this respect the disharmony among nations was reflected in armaments expenditures that easily kept pace with GWP. The U.S. and the U.S.S.R. maintained their arms "race" by developing the measures-countermeasures "games" to ever growing complexity; this included the deployment of several kinds of space weapons aboard maneuverable satellites--weapons employing various forms of "death rays" which could deliver lethal blows against other space satellites up to 1,000 miles away. The deployment of these systems soon came to symbolize national power and military prestige although their utility in a real war would be doubtful at best. Nevertheless, at least four other countries had deployed these weapons by century's end--China, Japan, France, and West Germany. Moreover, by then these satellites could be bought by almost any nation which was on sufficiently good terms with any of the above Big Six, as they soon became labeled. Brazil was

expected to make them the Big Seven soon, and some military experts predicted a proliferation of these systems to at least another dozen countries by the year 2025.

Non-Military Space Programs

Although the non-military U.S. space program was dampened by relatively flat funding it was assisted by increasing contributions from other OECD nations. Since none of these nations had developed its own STS (Space Transportation System) to compete with the U.S., their obvious alternative was to depend upon the U.S. Shuttle-based STS. NASA was pleased with this outcome since it reduced the burden of maintaining the Shuttle system and enabled them to develop a more comprehensive set of orbital transfer vehicles (space tugs). The combined budgets of the European and Japanese space programs increased to over \$1-billion annually by the end of the quarter--about a 4-fold increase. Although growing more rapidly, it was still less than 1/4 of the U.S. budget. To this it is necessary to add \$.9 billion from U.S. industries and another \$.5 billion from the private industries of the other OECD nations--mostly for investments in communication systems and space industrialization processes.

The U.S.S.R. space program continued to grow at its 2-3 percent annual rate, although as usual the allocations between military and peaceful purposes were hard to unravel. It was roughly estimated, however, that at the year 2000 the Soviet expenditures equaled those of all of the OECD countries. However, the Soviet space accomplishments, while significant, did not equal those of the U.S.-OECD programs, except in the

military developments. Their principal reusable launch vehicle, operational in 1988, was capable of sending 110 tons to NEO at costs roughly competitive with the improved Shuttle system. Perhaps because by 1991 they had built more of these launchers than they would need for at least another 10 years little improvement in these costs were to occur before the next century began.

Perhaps the principal surprise during the quarter was the growth of the Chinese space program. Although their GNP grew from about \$300 billion to \$800 billion during the period, and therefore to about \$900 per capita, they made a proportionately much larger commitment to their space ventures which, from a small beginning, rose by century's end to match the U.S. effort at about \$5 billion annually. The Chinese surprised the world by deploying during the '90s an automated "freighter" which could deliver a 1/4-million pound payload to orbit at roughly \$50/lb--which was less than the U.S. cost. It became quite clear that the Chinese had maintained a greater respect for science and technology than had the OECD countries and that they intended to be second to none over the course of the coming new century. Chinese presence at international science conferences had been growing rapidly during the quarter and by its end the number of Chinese scientists attending was seldom exceeded by any nation other than the U.S. Moreover, the quality of their contributions to the conferences was highly regarded. The number of contributions correlated strongly with the number of their representatives.

The group of prospering middle-income countries, Brazil, Taiwan, Korea, Argentina, Chile, etc., with a combined year-2000 population of about 1.5 billion people generally were much more concerned with economic

growth based upon imported technology than with space development. Efforts to develop the needed internal infrastructure to support a modern technological society were slowly succeeding but were not to blossom significantly until after the turn of the century--and even then great differences among these nations were to prevail in their relative successes.

B. 2000-2025

This quarter was destined to be a strange one for space development. On one hand, the technological capability existed in three major blocs--the OECD nations, the U.S.S.R. and its allies, and China--for impressive advances. On the other hand, a major distrust of the motives among these powers led to an increasing diversion of funds into military space systems and a 3-way cold war "paranoia" was to prevail that distorted the space developments.

During this quarter the Chinese chose to orbit many satellites, some of which were (erroneously) believed to contain nuclear weapons. In addition, they deployed ever more sophisticated defensive systems which included observational satellites, maneuvering inspection satellites, and a number of space-based anti-satellite systems which used destructive measures ranging from simple explosives to sophisticated laser and particle beam guns. Of course, they claimed that these were defensive measures to insure the viability of the Chinese space installations as well as to deter possible attacks on the earth's surface. Inevitably, the Soviet Union and the U.S. felt compelled to respond in kind and the space arms race was on.

Although each of the chief protagonists had established small lunar stations before the turn of the century and continued to expand them

during this quarter, no weapons were based on the lunar surface. Rather a series of unilateral announcements made it clear that each power intended to avoid military uses of the moon except for possible communication and control systems. This understanding permitted lunar observatories, laboratories, and exploration stations to proliferate in accordance with the international space laws that had been worked out under U.N. auspices during the '90s.

The lunar inhabitants understood, however, that if serious disputes arose which required legal resolution by international courts on earth, the viability of all lunar installations would be shaky. Moreover, the experience of living and working on the moon had a very strong psychological impact on the inhabitants. They found it extremely difficult to feel anything other than respect and friendship for their "neighbors" with whom they were in close communication. The political or military affairs on earth rapidly became as psychologically distant as the "big blue marble" was physically distant. As a result the lunar inhabitants rapidly gravitated toward a common feeling of belonging to a lunar society which, however "primitive," was beyond traditional nationalism. The longer one remained on the moon the more did nationalism appear to be a ludicrous arrangement for organizing human society. (This judgment was to lead to the formation of the United Lunar Authority, an international lunar society which eventually became independent of earth governments.)

The Great Space War

One difficulty in space during this quarter was related to a growing fear of war and some concern for the manned installations in earth orbit--especially the space industries for which there was so much hope. Private

Investment in expensive new facilities continued at a high level despite the apparent war prone environment. Most people would not believe it could actually happen, although in retrospect it was clear that the situation had become so unstable that it had to explode before long. Although it was clear that any new space facilities could very readily be destroyed by enemy weapons constantly within view, except for sporadic situations investment continued to soar. It was true that theorists and war-planners considered the small number of R&D and maintenance personnel to be highly vulnerable "demonstration targets," if one of the three powers wished to flex its military space muscles. Still, there was no reduced emphasis on unmanned systems or restraints on private investment in space development.

This space-based powder keg was inherently unstable as a deterrent and resulted in the Great Space War of 2019. In principle, this was a war which could be fought by generals and their extensive staffs of officers, scientists, technologists, and various other consultants. It could be played like a chess game with little being destroyed that was even visible and few human lives involved--providing the war did not escalate to a surface exchange of weapons. Perhaps the script could have been written in advance. A space war was not deterred because a "clean" victory was possible, in principle. No power would deliberately escalate to even limited use of highly destructive surface weapons. Yet that same possibility may have made the war inevitable.

How the shooting started may never be known. Too many irreconcilable claims and accusations have been made that were beyond investigation. All that is clear is that the Soviet Union and the Chinese not only blamed each other for starting it, but for escalating it by destroying U.S. satellites in an attempt to catalyze U.S. reprisals against the other. It was all

over--the space battle that is--in one day. Almost everything of potential military value that could be shot at, was--often more than once just to make sure. The measure-countermeasure game was played out in full. About 98 percent of all the military satellites and 100 percent of the orbiting military stations had been reduced to scrap in orbit. About half of the non-military satellites on earth-oriented missions were lost. For both the Soviets and Chinese all of their personnel manning space stations and space industries were casualties. Fortunately for the Americans only one of their manned installations was fired upon. Altogether, less than 300 lives were lost but perhaps \$200 billion worth of equipment (original cost) was destroyed. The major blessing, however, was that the destructive orgy did not descend to the surface of the earth. Indeed, very few human beings knew that anything was happening until it was all over; they were incredulous when it was first reported by the news media. Even then it took weeks or more to sink in fully. A major war without sound and fury which began and ended in a single day? That concept was beyond the human experience except for a few prior fictional portrayals with some accidental similarities, but those had never had much impact in any event. On the moon the stunned lunar inhabitants had monitored many of the events, but they did not know how to respond to the strange sudden insanity of it all.

The reaction on earth took awhile to go through all the steps of what appeared to be a well-rehearsed play. The accusations, recriminations, investigations, deliberations would rise up, interact, and subside--over and over like waves from several simultaneous epicenters of gradually diminishing power. But from the beginning wiser heads knew what the main outcome would be. The orgy was over--for good. Space would be returned to peaceful purposes once again. It would take decades before some

investors would be sufficiently convinced that the risk would be worthwhile--but, as generally happens after wars, peace appeared secure before long and investment began to return. The more astute private investors reinvested rapidly and benefited greatly. As a result, a few great corporations were to arise and dominate the commercial space enterprises (these are described in Part II). The Great Space War has been the only space war in our history. Fortunately, the casualties were so few.

Technological and Economic Progress

While the military powers were devoting much of their technological capability to space weapons and space defense systems, the scientific, exploratory, and industrial uses of space were also pursued by each of the major powers but at a relatively low level. Nevertheless, lunar-based science and technology, asteroid mapping, unmanned Martian rovers, and then small Martian laboratories by the Chinese and the Americans were among the highlights of the quarter. Large space colonies were not seriously contemplated although considerable R&D on the life science aspects of self-sufficient, long duration operations in zero- or low-gravity were steadily pursued and much progress was made that was to be field tested during the next quarter.

Meanwhile the developing countries were making reasonable economic and technological progress. Economic growth ranged from 4 percent to 7 percent annually for the more ambitious countries, and 2 percent to 4 percent for the more traditional cultures. The larger nations (Brazil, Mexico, Argentina, India) became more interested in space activities as their technological capabilities expanded and as they saw some potential for its economic applications. Of course, the Great Space War set all such

ambitions back for awhile, but they were reemerging as the quarter was ending.

In an important sense the Space War was to become a boon to future space programs for two reasons. First, it was to lead to an effective international treaty that was to ban development of destructive weapons in space. Second, none of the subsequent funds for space development would be siphoned into costly military hardware--the debris of which was to be orbiting the earth for a long time. During the next quarter most of this debris was collected for special orbiting museums as permanent reminders of that notorious day--and has furnished some of the more fascinating points of interest for subsequent space tours.

C. 2025-2076

Aftermath of the Space War

The treaty restricting nuclear weapons in space to the Anti-Nuclear Command (see below) became effective in 2031, twelve years after the Great War. But its effect was anticipated well before then since none of the belligerents had moved to replace their prior systems. The public's attitudes--as reflected by the actions of their government leaders--had become all too clear. Indeed, the spill-over to other military systems and philosophical concepts led to a gradual withering away of the former arms races. During these last 50 years the perceived need for elaborate forces for offense and defense under the umbrella of various deterrence concepts has faded away until only relatively rudimentary capabilities remain--just minimal "light cover" systems which can keep the military R&D establishments active in the event that unanticipated political

developments arise that make renewed strategic military forces desirable once again. Currently, the need for the light cover and even the R&D is being questioned.

The United Lunar Authority

George Lincoln was an unusual genius who became entranced with the idea of the development of space and space colonization as a vital part of the manifest destiny of humanity. At a critical historical moment he found himself in a position to move both men and nations in that direction. It was largely due to him that in the year 2001 the Lunar Treaty was signed in which the U.S., the Soviet Union, China, West Germany, France and Japan, as well as (later) many other powers, joined together in a pledge to create a truly international lunar facility which would be available, under reasonable terms, for use by all nations and individuals. By 2011 the lunar facility included two telescopes (one of Soviet and one of American design), several launching platforms, two electromagnetic accelerators, facilities for logistics to be used by all parties, and so on. Unfortunately, after 2010, relations among these nations began to deteriorate sharply and a new "coldness" arose which focused considerable attention upon the use of space satellites for defense, ultimately leading to the Great War of 2019. Fortunately, however, the United Lunar Authority, which was nominally under the direction and the authorization of the U.N., was able to preserve its international character at a high level. In the years of its existence before the Great Space War its personnel had developed an extraordinary sense of unity and felt independent of national considerations. Their attitudes became quite different from the nationalistic ones which characterized most groups on earth. It was their sense

of detachment from earth and the ever-growing bonds of a common lunar culture that led them to a one-for-all and all-for-one attitude. Furthermore, the selection of personnel was strongly affected by George Lincoln. Most Lunarians became infused or imbued, partly by desire and partly by the effect of the environment, with Lincoln's sense of mission and "religious" zeal for unity. They soon lost any sense of identification with the international rivalries of earth (except as these were clearly constructive for the developments in space).

By 2035 the United Lunar Authority had gradually evolved into a position where it was trusted by all national groups on the lunar control issues of most concern. Some of these issues were very important to the survival and continuation of both military and non-military operations on the moon. Although a partial separation of selected lunar activities did occur as a result of pressures from earth towards "nationalization" of these activities (that is, physical separation of facilities for separate national purposes), on the whole the attempts of earth authorities to extend this process were effectively resisted. (Before mid-century the earth authorities, to their astonishment, had learned that a genuine international body was operating on the moon.)

Lunar Command

An important breakthrough occurred after the Great Space War when, in 2032, the international control of space systems was organized through the United Lunar Authority (ULA). This powerful organization in turn was asked to organize the Lunar Command, which in 2035 was given basic operational responsibility for the International Space Defense System (ISDS).

(See Appendix B for another version of a Lunar Command.) Various national space defense forces were dedicated to this system. The ULA never received the ultimate authority to utilize these weapons for their deterrent mission; this was kept by the Temporary World Defense Authority (TWDA) and by various national governments operating independent systems. However, the Lunar Command actually controlled the day-to-day operation of the ISDS forces, most of their maintenance,* and "owned" the Lunar headquarters which could transmit the orders and carry out the agreed-upon policies. The Lunar Command was given very restrictive guidelines; but within these guidelines, they could and did operate quite independently in practice. This was generally accepted as a reasonable arrangement until about 15 years ago, when some began to worry about the great power held by the Lunar Command--because after that time they were no longer dependent on supplies from earth. Also, the need for the space defense system has greatly decreased according to most recent competent analysis. War or even the threat of war now seems very unlikely to occur among the large nations of the world (see Appendix C); during the last decade only two of the smaller nations have even hinted at escalation of local conflicts. Of course, many of the small nations will still wish to retain their "Anti-Nuclear Command" (ANC) which is also stationed on the moon.

*Most of the personnel training and systems procurement were controlled by the national governments or the TWACA (Temporary World Arms Control Agency). As is well known, the latter organization is now the oldest "temporary" organization in the world.

Anti-Nuclear Command

Soon after the Lunar Command was established the Anti-Nuclear Command (ANC) was set up on the moon under the direction of the ULA. It was sponsored by a number of small nations--ones who did not wish to own nuclear weapons themselves but instead contributed to the ANC's ability to obtain and deploy such weapon systems. These were the only nuclear weapons allowed to be maintained in space, and by international agreement their only purpose was to retaliate (in a tit-for-tat fashion) against any country which used nuclear weapons against one of the non-nuclear sponsor countries. These weapons could not be used in defense of a sponsor which subsequently developed an independent nuclear force. It was also agreed that if the ANC was ever disbanded, its weapons would be removed from space and dismantled by the ULA. This arrangement made it feasible for the sponsor nations to refrain from developing their own nuclear weapons systems and it was widely applauded as a relatively acceptable form of "nuclear proliferation"--certainly preferred to many other alternatives. It gave the small nations an independence and self-respect that they would not have had as dependent clients of one of the great powers, in order to feel safe from nuclear threat or nuclear aggression.

These nations played no active military role subsequently, but the mere existence of the ANC probably helped maintain a smoother and more secure peace and may have been much more important than is generally realized. Because many dire things did not happen, people do not realize how important the ANC was to world peace. The final peaceful demise of the ANC occurred and was celebrated in 2066.

Societal Changes

Perhaps most important for general world progress and political stability was the elimination of the grinding poverty which up until this century had characterized most of the world's population throughout recorded history. That poverty had also been closely associated with poor health, illiteracy, extreme corruption, callous urban societies, incompetent governments, and repressive authoritarian societies--in deeds, if not in form. Nearly all of these conditions have disappeared during this century. What vestiges remain are very unlikely to survive to the year 2100. Today almost every child is born wanted, and has a guarantee of appropriate nutrition and health care. Moreover, prior genetic screening essentially guarantees that it will be free of serious mental or physical defects at birth. It is hard to conceive of a plausible scenario leading once again to illiterate subcultures; also violent crimes have become quite rare, having had a negative growth rate for at least the last 40 years. Although corruption has not been eliminated it has been greatly reduced and does not exist anywhere in any of its former virulent forms.

By former (i.e., 20th century) standards ours is a far more wealthy and egalitarian world. The average income today is almost 7 times that of a century ago. Perhaps more important is the fact that the former very poor countries have an average per capita GNP that is at least 20 times that of 1975. Moreover, they are the ones whose economies are expected to grow most rapidly in the future, an almost inevitable outcome about which there is little disagreement among our experts.

Technological and Economic Progress

When we leave the social and political arenas it is possible to characterize the progress in the more technical areas much more easily. Indeed, wherever appropriate theories and initial data exist most problems can now be expressed in a language which computers understand, and one or more solutions are usually readily generated--or the cost of producing a solution can be determined. Thus, to produce ultra-pure diamond fibers, or develop a fusion engine with 92 percent efficiency, or determine the chemical composition of petroleum to .1 percent accuracy for the top 300 components, or predict next month's precipitation within 2 percent--these are straightforward problems with straightforward solutions. Today it is taken for granted that improving technology is a general characteristic of the entire world and that it will lead to even more surprising outcomes--despite the dwindling fraction of the population engaged in these activities.

Our "colonies" in the different regions of space specialize in the various technologies which make them most valuable. The lunar and asteroid colonies are furnishing materials for space processing industries. The La Grange point colonies build large space structures: habitats, exploration vehicles, fusion propulsion engines, antennas and electric power systems. The orbiting factories produce many thousands of products and components for both earth and space uses. These include satellites, electronic instruments, ultra-pure crystals, computer "chips," cryogenic alloys, medical specialties, metallic hydrogen, space foods, metallic foils, foams, whiskers, and so forth. The huge space depots specialize in refueling and maintenance services for spacecraft and tourist facilities.

Tourism in space has become one of our most rapidly growing space industries, especially during the last several years when the cost of the minimum (2-day) NEO tour fell to \$9,000. Indeed, there is a shortage of touring facilities which, because of government regulations, are unlikely to be expanded rapidly enough to meet the demand for some time to come.

The GWP today is about \$110 trillion; roughly half of that comes from the countries with large commitments to space: the U.S. whose space program is integrated with those of Japan, Germany, Brazil, France and others; China; and the U.S.S.R. and its eastern European associates. These three countries and their collaborators represent about \$65 trillion of the current GWP. Their respective annual space budgets are roughly \$100 billion, \$200 billion, and \$100 billion. In addition, from the U.S. group about \$200 billion annually comes from private investment--mostly profits from tourism and space industries being plowed back. Thus, about 1 percent of the GWP of the countries actively involved in space development is being allocated for space purposes. This allocation is high by historical standards but is not expected to diminish.

A MODERATE SCENARIO

PART II: THE ROLE OF THE PRIVATE SECTOR

In retrospect, one of the most significant forces in the commercial development of space was of two extraordinary American men, George Lincoln (described earlier) and Henry Geneen. Both about the same age, the men had been space buffs since their teens, and both had been exposed, as students, to the influence of Krafft Ehrlicke, and Freeman Dyson in the 1970s. Otherwise, they were about as different as two Americans could be.*

A. Spacecorp

Spacecorp was the commercial space organization which first employed Henry (Hank) Geneen. He put together an extraordinarily dedicated group of space engineers and scientists, received a surprising amount of support from government, private institutions and influential wealthy investors, and started a large number of commercial activities in space--almost simultaneously. More than half of these activities succeeded, and became the focus of Spacecorp's business. The failures were frequently written off as basic or applied research or sometimes could be charged to various national governments or international authorities. As a result Spacecorp was incredibly successful in its ventures. In addition Spacecorp spawned a series of earth-related subsidiaries. Because it proved to be more efficient than its competitors in most space activities the United Lunar Authority came to depend upon Spacecorp as its main contractor in preference to its own subsidiary, Lunar Corporation.

*The reader can think of Henry Geneen as a combination of Henry Ford and Harold Geneen and of George Lincoln as a combination of George Washington and Abraham Lincoln.

In 1998 Geneën, as President of Spacecorp (the successor to INTEL-SAT), started a new expansion which led to the unexpectedly rapid commercialization of space. We all have heard the phrase "an institution is a lengthened shadow of an individual"; never was this truer than for Spacecorp. Even before Hank (as he became generally known) came to the Presidency, Spacecorp was an energetic organization, multinational in both ownership and operation, with a heavy governmental investment. While INTELSAT was at the cutting edge of technology, it had never really pursued expansion aggressively and creatively. Thus, it was due to Hank that in 2009 the first major expansion occurred in the space tourist industry as well as the extraordinary expansion of the space-based power station industry (though Spacecorp was eventually--in 2045--overtaken in this industry by the Comca Corporation which, as is well known, is mostly owned by German, Japanese and Brazilian investors and governments). But Hank's true genius shone in the field of space industrialization which, together with tourism, became Spacecorp's principal successes.

B. Space Industrialization

In the 20th century there had been much speculation about the commercial potential of space-based manufacturing. As it turned out the reality surprised most of the forecasters since many developments were totally unexpected. The relative ease with which manufacturing processes could be kept free from vibrations, gravity, contamination and corrosion was extremely useful. The perfection of a series of cryogenic space-alloys which were super-conducting at relatively moderate temperatures (below 150° Kelvin) was probably the most spectacular early innovation.

There is scarcely an electrical system in the world today of any substantial capacity that does not use these alloys and the associated advanced technology.

Another result which proved to be much better than expected was the extraordinarily long mean-time-to-failure in space of properly designed equipment. The earth environment is, as we can now fully appreciate, basically hostile to smooth failure-free operation of machinery and equipment in ways that do not--or need not--occur in space. Of course, space industry is not immune to hazards; there are cases where sudden solar flares, meteorites, ionic radiation, or very high energy cosmic rays have caused problems, but these have been relatively infrequent--and now can easily be circumvented by proper design--easily, that is, compared with the hazards the designer has to face for "equivalent" installations on the surface of the earth.

C. Tourism

Soon after the year 2000, it was widely noticed that an increasing number of very wealthy--or specially situated--people accepted the concept that it was imperative to visit outer space during their lifetime. At that time a trip confined to a low orbit cost a minimum of \$25,000. For about \$50,000, a trip, even if short, normally combined a number of activities: about twenty earth orbits (to give a relatively complete earth perspective), a visit to a space station and a day or two in nearly geosynchronous orbit, where a tourist could float and absorb the awesome feeling of the cosmos while able to gaze upon the spectacular blue marble, his own earth, stationary "below." These cosmic perspectives still make veterans gasp.

Almost every new space traveler soon feels an overwhelming sense of both the unity of mankind and the fragility of the earth and its inhabitants when first observing the "little globe" some tens of thousands of miles away. Most have claimed this feeling to be the most aesthetic or religious experience of a lifetime--independently of the observer's prior aesthetic or religious bent. The fact that this experience is still an extraordinarily moving one should give us some indication of what it meant to the early astronauts of the late 20th century and the "tourists" who followed shortly thereafter.

It is popularly believed, and many analysts concur, that the space tourist industry was one of the major forces in reversing a surprising social trend which occurred within the developed countries during the last part of the 20th century--the trend against science, technology and industrialization. Through their space experience the tourists found and communicated a renewed sense of a challenging frontier, of the wonders of technology and science, and--most of all--of an exciting new perspective on the meaning of the Universe. The new challenges to--and the prior accomplishments of--science and technology led to new concepts of man's purpose, or mission. Many began to think in terms of a "manifest destiny" or a holy mission to "colonize," first the solar system and eventually the Universe. The Universal Party dates its inception to those strongly affected individuals who in 2001 had their first orbiting experience. A similar beginning is on the record for many 21st century religious movements. Probably the most influential of these experiences was that of Pope Peter II in 2010. The impact of his space trip on the famous "Extra-terrestrial Encyclical" is too well known to comment upon here.

Almost every child today is taught that sooner or later he will take at least one trip to outer space. This, of course, will not be feasible for everyone this decade (the current cost of a 15-day lunar excursion is still about \$40,000) but it will be practical over the life span of today's adolescents. Indeed, Spacecorp, Solar Systems, Inc., as well as the United Lunar Authority, with the endorsement of most governments, are dedicated to making it possible. In any case almost every child has read or watched on Holovision a rendering of Bobby and Betsy on the Asteroids and Minnie the Space Mouse, as well as some serious programs, articles, and books on space travel. Mankind has attained a high degree of solar consciousness, perhaps a necessary prelude to--and part of--a true Cosmic consciousness.

D. Space Buffs, International

This organization (formed in 2010) admitted only space enthusiasts who had had direct space experience, either as a member of a space development project or as a tourist. It became a very active organization, intensely oriented towards the rapid and pervasive development of almost every aspect of space. They had tenuous but important connections with both Spacecorp and ULA. A general community feeling arose among these three groups, though occasionally their interactions led to some clashes of interest. One of the most significant early accomplishments of Space Buffs, Intl. was to help bring George Lincoln into a position of great prominence and influence.

Possibly their greatest single accomplishment was the organization of Solar Systems, Inc. which soon became both a competitor and a complement to Spacecorp and Lunar Corporation. Because Space Buffs, Intl. had so many of its members in positions of power within both influential

private organizations and agencies of various governments, they were able to charter Solar Systems, Inc. (SSI) as a fully private company with important political links to many governments and with access to an extraordinary amount of government help. SSI soon became a kind of quasi-independent arm of the United Lunar Authority (ULA), and became trusted by ULA almost as much as their own departments. As a result, ULA achieved what they felt was a useful counterpoise to Spacecorp.

E. Solar Systems, Incorporated

This institutional breakthrough occurred in 2020, the year after the Great Space War, when Space Buffs, Intl. organized Solar Systems, Inc. SSI soon became the most rapidly growing "private" corporation in world history, attaining an average annual growth rate of 15 percent in the forty years between 2020 and 2060 (or an overall factor of about 250). With an initial equity of \$200 million plus \$800 million of borrowed money, it then controlled \$1 billion. It doubled its assets (on the average) every 5 years for the next forty years. While its growth rate has since slowed substantially (to about 6 percent), it seems almost certain to become the first \$5-trillion privately-owned corporation in mankind's history. With 40 percent of its assets in space SSI controls about 20 percent of the tangible wealth in the extraterrestrial region of the solar system (this would be consistent with a dollar output ratio of 10 to 1 and about \$1.0 trillion of Gross Space Product). SSI now is substantially larger than its chief competitor, Spacecorp.

The decision in 2025 to allow SSI to acquire (at very advantageous terms) most of the property of many of the obsolete Space Commands was of

major assistance to the extraordinary expansion of Solar Systems, Inc. Of particular importance here is the fact that SSI became the major contractor for the United Lunar Authority and the Lunar Command--more or less replacing Spacecorp in this role.

Many people think of SSI as equivalent to a space-based government; its power and influence are indeed great. Partly as a result of its innovation and subsequent support by Space Buffs; Intl., partly as a result of its control by Space Buffs, Intl. and of its unusual policies in operation, it also has many of the aspects of a crusade and often appears to be more of a fellowship than a business. This orientation has been deliberately supported by design and policy. No other private international corporation has such a genuinely emotional dedication to its mission--one which is symbolically supported by a flag, by songs, and many rituals and totems. The relationship of the SSI cadres to the parent organization recalls more the 19th and 20th century sense of patriotism than just the current more common sense of community and social contrast. SSI maintains a complete and very dramatic record of its history in its holovision library--to a degree which does not exist in any other corporation we know of. The continued growing demand for its old holos surpasses that of many commercial productions.

Few SSI analysts expect its former growth rate to be regained in the future. That rate has slowed down, it is believed, not because the corporation is less creative but, in part, because there is less urgency for commercial innovation, in part because of greater political opposition from other industrial organizations and, to some degree, from more effective competition. In any case, its economic expansion today is more a genuine expansion by internal growth--it no longer attempts to grow by

acquisition, by merger, by outside capital, or by absorbing other ventures. It may even have taken over too much; some SSI adherents have expressed a concern about the potential of its inherent power and pervasiveness and/or the likely diseconomies--either now or in the near future--of its great size.

In defense of SSI, it should be noted that they own less than a quarter of the factories in the asteroid belt and less than 20 percent of lunar industrial capacity. Their strength lies in the colonies at the L-4 and L-5 Lagrangian points that produce power systems, vehicles, space habitats and factories, and, of course, a large array of computers and robots. Also, their commercial installations on the Moon and Mars are among the most advanced. Even so they produce less than half of the processed lunar minerals supplied to space factories and to earth. The fields in which they most excel are in specialized computer systems, robots, space factories, orbital transfer vehicles and space tourism.

In any case, almost all of its critics and even many of its supporters had begun to believe that its sheer size was a potential threat; and most of us were pleased when its growth slowed after 2060. But most of those who for many years opposed the projects of Solar Systems, Inc. have conceded that it played a fantastic, even glorious, role in space development since its inception--and constitutes a very useful balance to Lunar Enterprises, Inc. and Spacecorp. SSI has come under much criticism here on earth. Some of this criticism may have been justified, but much of it has arisen through normal clashes of interests, or from a certain amount of early envy--which, some say, is increased by a little bit of residual paranoia.

None¹ of the above is meant to challenge the reasonableness of the recent legislation introduced in the U.S. Congress and the World Legislature to place controls and some limits upon the activities of this corporation, though many critics are claiming that this legislation may be unconstitutional or ill-advised.

Concordat

Probably the most significant single Space/Earth "confrontation" was the one that resulted in the famous "Concordat" of 2038. Previous to that, activity in space by private ventures was organized in technologically advanced countries by various international corporations and essentially had been untaxed by any governments, either singly or in groups. Only when income went back to earth was its owner ever taxed. This greatly helped to encourage the rapid expansion of industry in space. However, an increasing number of people felt that space activities were not bearing a fair share of earth's overhead--or even paying for many earth activities that supported those in space. In addition, there was always the serious issue of a more equitable redistribution of income. By 2040, it was claimed that many people in space lived in what was often pictured as fantastic luxury. Of course, many of these luxuries were grossly exaggerated, others were necessary or at least useful--and most in space did not share in the more extreme activities--or even condone them.

Under the Concordat the principle was established that no direct taxes should be paid by permanent inhabitants of outer space to any earth government covered by the Concordat--even when operating in territory

nominally under the sovereignty of the earth authority. Earth organizations, of course, charge their space customers in a normal fashion for supplies and equipment. Even when these goods and services are priced quite competitively, their prices usually include many overhead charges and various taxes. However, other than the indirect taxes included in the price of equipment and supplies, no direct taxes were to be placed on space income or property. This policy subsequently led to great pressures for change but all these pressures have been resisted.

Of course, by now various commercial space ventures voluntarily contribute more than \$20 billion a year towards the promotion of social and economic progress on earth--or other philanthropic activities (including many that encourage new space activities or interest). Many critics argue that it would be appropriate if this voluntary contribution were increased and made compulsory, but they evidently chose not to understand and accept the extraordinary intensity with which the Solarian societies defend the principle of "no direct taxes." Earlier in this century this no-direct taxation concept was not an important issue because most of the ventures were government-owned or so firmly earth-based that their income tended to go directly to the government or to the parent earth corporations. Now it is a settled issue, so well settled that most analysts believe that it is really a non-issue.

The above discussion, of course, does not include regions in space solely controlled by some of our centralized economies who can still do what they please, but it does include all the countries which have signed the Concordat.

To some extent this freedom from direct taxes must have motivated some emigration from earth. It doubtless has helped enormously the spirit and pace of space development generally--and very recently of the retirement industry, in particular. The very wealthy people who have retired to space habitats have tended to invest much of their wealth in private space ventures, thereby creating a major source of private capital for outer space.

Culture in Solar Systems, Incorporated

One great competitive advantage which Solar Systems, Inc. soon came to have over most of its competitors was its growing reliance upon space-born, space-bred, scientific, technological, and managerial personnel. As a result these space people developed a very high morale, special sense of unity, a dedication to their mission, and they became incredibly ingenious at exploiting the resources of space for their industrial potential. Further, often the operating expenses, construction costs, and exploration costs were much less than that of their competitors because of this dedication, creativity, decentralization, and extensive experience. SSI also appeared to many to take many more chances--both physically and financially--than did other companies. This is not to say it slighted safety precautions, but it did not allow "excessive" safety precautions to stand in the way of important projects. Its safety record was about as good as any, but its safety regulations and practices would be considered unacceptable by many of the other companies--particularly those regulated by governments. Similarly, it has not been financially imprudent; its record confirms this. But its emphasis

on local decision by experienced and dedicated people who really cared about the cost-effectiveness of each task gave it an important flexibility.

We should not think of Solar Systems, Inc., as an ordinary company. It is more a kind of relatively lightly managed, permissive, functional arm of the community or the government than a normal business corporation. It has many of the elements of a big family, but is very decentralized and has an extraordinary amount of independent decision-making by its employees. It is quite surprising that it has managed to achieve the ends of a normal business corporation with this unusually decentralized and permissive management.

Business and management experts who have studied Solar Systems, Inc. have argued that it is very much dependent upon the shared backgrounds and concepts, the high morale, the sense of unity, of altruism, of common goals, and of respect for technology and science that occurs because it has so many space-born and space-bred personnel. These employees have all been raised to feel a strong sense of trust in as well as responsibility for their associates and companions and, indeed, for the other SSI personnel, also.

Both academic and business observers who have studied SSI have been astonished at the degree to which SSI personnel are conscious and knowledgeable about what their associates are doing and to find that almost none would consider acting irresponsibly or unnecessarily risking any lives or property.

Conceptually, there remains the important problem of terrorism that emerged at the end of the last century. Fortunately, despite their

apparent vulnerability to such threats, space installations have not experienced any such incidents for over 20 years. In part because many "bottle-neck" situations exist requiring control or examination of arriving or leaving people and baggage, it is believed to be almost impossible for a terrorist to make a "get-away" or to hijack a space vehicle successfully. These and other reasons have made the terrorism in space a very small problem--particularly as compared with the same problem on earth. There is a constant sense of vigilance and protection of the system whether or not one is worried about terrorism. Little is taken for granted. It is different from the earth environment where, even now, so much appears to be taken for granted. Every space installation has been created by human effort and must be conscientiously maintained and serviced. Every potential disaster becomes a community problem. Any individual who commits a careless or irresponsible act is noticed and feels the community's censure.

This customary vigilance and consciousness tend to diminish gradually in installations which have a long-term history of smooth operation. The newer generations, to some degree, take their safety and welfare for granted--much as people on earth tend to take their environment for granted. However, even the current generation clearly understands that their environment was created and is maintained at a high quality by human beings operating within an equally human and equally high quality organizational context, and that without continual maintenance and renewal their culture would soon decay and disappear. The same may be true of much of our current environment on earth, but here it is easier to maintain the illusion of naturalism and even allowing some people to be carefree or even irresponsible.

A MODERATE SCENARIO

PART III: THE NEXT 100 YEARS (2076-2176)

I have been asked to offer some projections about things to come. Naturally any such projection can be wildly wrong since every space buff like me holds an optimistic view, at least secretly. Typically one of these views, if carried out over a 100-year period at a "nominal" 10 percent growth rate, gives about 14 doublings or about a 14,000-fold increase in overall growth. In comparison, over the last 100 years the GSI* experienced about a 60-fold increase. Moreover, we need to face up to the argument that space development is no longer in its infancy and thus its growth may be slower in the next century than in the last one. This maturing is fairly evident now because it is difficult for us to project good new vistas to conquer without entering into "science fiction"-type developments to a large extent. One hundred years ago, much of what we find in space today was reasonably envisioned by sensible forecasters of that time. We have not exceeded the speed of light nor evolved methods of transporting people to distant planets by "teleportation," whatever that word is supposed to connote. Of course, we have made some progress which could not have been predicted and therefore would astonish the scientist of 100 years ago--e.g., the focused magnetic monopole array which permits the exchange of kinetic energy between orbiting bodies without any mass losses, and which has greatly reduced the cost of orbital transfers. But even in 1976 scientists were confident that many unpredictable developments would occur. Undoubtedly, if the people on earth had been willing to invest more in space science and technology--for example to make it an increasingly funded

*Gross Space Investment (including military expenditures in 1976).

field rather than an erratically funded one--its present size and scope could have been vastly greater and the surprises much more numerous and impressive (for an analogy we can compare a potential 14,000-fold increase from an average 10 percent growth rate with the 60-fold one actually attained--average growth rate about 4 percent). However, erratic budgets--with all their inefficiencies--are much more consonant with political realities than the smoothly growing ones which planners prefer.

Consequently, to make a realistic, rather than idealistic projection for the forthcoming 100 years, and taking into account the maturation of space exploration and space industries, we might project that the growth in space might be 2 or 3 times that of the economic growth on earth. The latter is expected to grow less than 1 percent per annum on average, for reasons which our economists and social scientists have explained quite well, and on which there is a general consensus. Thus, barring the unexpected, the GWP should about double over the next century and the world's annual investment in space might increase to roughly 5 times its present level--or to about \$3 trillion per year.

Taking this to be a reasonable number the next task is to project the manner in which space might be exploited and then to ask what kind of specific developments might result. For this purpose we consider the topics of: tourism, industry, subsidized colonies, exploration, and science. Naturally a great amount of overlap exists among these--a fact which we will ignore. Also we will ignore many other relevant facets of the expanding space-based services such as weather prediction and control furnished through government agencies or government-related institutions that are now not included as space investments, as well as questions related to

private versus public financing which economists consider to be quite important.

We begin with tourism as the most rapidly growing aspect of space. A hundred years from now we believe that essentially everyone on earth will tour space at least once during his lifetime if it is physically possible--as I assume it will be--and that about a 1-month tour in cis-lunar space, including about a week on the lunar surface, would be a reasonable average. After the next 100 years our projection is for the transportation costs to fall to about \$10,000 and I allow another \$10,000 for other costs. \$20,000 per person and roughly 100 million tourists annually comes to \$2 trillion, or 2/3 of the assumed total space expenditures. (The required annual investment in our steadily growing tourist business has roughly been equal to the gross annual receipts--according to Solar Systems, Inc.)

Of the \$1 trillion balance my consultants and I have agreed that an appropriate division among the four remaining sectors would be industry, 60 percent; subsidized colonies, 20 percent; and exploration and science, each 10 percent. These percentages are unlikely to be in error by a factor of 2 although the \$1 trillion total is a soft number which could easily be wrong up to a factor of 5, perhaps more.

The annual investment of \$600 billion in space industries would be about 4 percent of the total annual industrial investment projected for 2176. This figure would be much greater if the electric power needs on earth were required to be space-based as many people (in the old days) thought would be necessary. But space electric power is expected to be used to produce instruments, components, and materials in space for use mainly by other space industries (including transport) and for the end

products consumed in space by space tourists, colonists, explorers, and scientists. Secondly, space industries will continue to expand their products and processes which are useful on earth and which otherwise would be unavailable, or too expensive if made on earth. At present this second category is about 10 times greater than the first; but the first is expected to increase much more rapidly as both tourism increases and as living in space becomes increasingly self-sufficient, in the full sense of the term. Thus we foresee a gradual shift in emphasis over time toward production in space for consumption in space, while the overall demand for space products and services increases substantially more rapidly than does the GWP.

The expenditures on subsidized colonies refer primarily to the costs for establishing and maintaining new colonies in space prior to the time that they became self-sustaining. This process is expected to be an unending one as long as space exploration proceeds and the colonization that follows--whether in orbit or on planetary surfaces--is considered desirable. To date we have subsidized such colonies on and around Mars, around Venus, and in the asteroid orbit--in addition to those in cis-lunar space and, of course, on the moon's surface, most of which are now self-sustaining. The estimate that twice the cost of the exploration will be required for subsequent subsidies of colonization is roughly consistent with the experience of the past 50 years and no important arguments have appeared to question this seriously. Of course, this experience makes the projection only plausible, rather than "correct."

In addition, the recent experiments with retirement communities suggest that space living might become a desirable mode for many senior

citizens who are not too attached to their routines on earth. At present the estimated costs are relatively high for retirement in space but not beyond the means of the wealthier segments of the population. But these costs are expected to fall substantially and possibly come within the means of the average retired citizen in perhaps 50 to 100 years--although many analysts are dubious about the economics of this projection since there is insufficient experience at present. Of course, such colonies might also be subsidized. However, we have only included in our estimated expenditures the subsidies required during the formative stages. Social experiments of this kind will proceed for decades and possibly for more than the full hundred years of this projection. In any event, we have not allowed this potential development, whose cost and/or desirability is quite uncertain, to significantly affect our projected total budget for subsidized colonies.

I must admit right away that the separation of space exploration and space science, although conceptually easy, soon becomes difficult if we examine the subjects in detail. Some scientists claim it is analogous to splitting an animal in half--that each is so totally dependent on the other that budgetary separation makes little sense. Perhaps they will forgive my crude "surgery" as I proceed with this artificial splitting for ease of discussion.

Up until now a large variety of automated probes and instrumented vehicles of various types, which I shall group together as robots, have been sent to inspect every planet in the solar system and their satellites. The information from these probes has given us a remarkably improved picture of the solar system and we will continue to get more from these

marvelous robots. Our manned orbital explorations of Mercury, Jupiter, and Saturn have been more in the sense of pilot projects than of a full-scale scientific assault on the exploration missions. Of course, Jupiter itself is especially difficult because of its intense radiation fields which prevent too close an approach. But this year we expect to put the first permanent installation on the surface of Mercury as one of the celebrations of our Tricentennial. Manned surface stations are being planned for the smaller moons of the outer planets: of Jupiter in 5 years, and of Saturn perhaps 5-10 years later, if the Jupiter mission is successful. The Interplanetary Exploration Society (IPES) believes that within 30 years we will put the first men (temporarily) on Pluto and, within 50 years, a permanent station on that planet.

However, as the members of IPES agree, the ultimate mission of their organization is an expedition to one of the nearby stars. There is little prospect of such an expedition during the next 100 years, however, unless some very unexpected and startling breakthroughs occur which could make such a journey appear feasible. Until now we do not know if even one of the 48 interstellar probes which were launched during this century will reach its destination sufficiently intact to return a message that it has arrived. At least the first 6 have failed in transit since their messages are overdue and they were functioning after their launches. However, there seems to be no shortage of predictions of successful voyages--or preliminary designs of interstellar "vehicles" which might be launched with anywhere from 4 to 10,000 people during this or the next century, depending upon various assumptions about future technological progress.

In a relatively pure sense space science and technology have accomplished the usual set of miracles during this century--the full appreciation of which has, as usual, been limited to the relatively small portion of society which devotes the time required to understand what has occurred. For example, the study of the sun has evolved to the point where we can now be confident of our capability of predicting accurately the number and sizes of the "sunspots," those great flares that earlier were a threat to manned activities because of their potential for sudden violent emissions of destructive radiation. Now the threat is of minor concern since flares are accurately predicted in advance by the new Solar Computer. In addition, the "small" fluctuations of the solar constant have been accurately modeled. This is also important because the accuracy of these predictions gives us confidence, not only in the life cycle of the sun, but enables us to understand the interior processes in all stars for which the required data is available. This already includes over 100,000 stars of our galaxy.

To the watchers of planets in distant solar systems the progress of astronomy has been a source of great satisfaction. The planets which can now be counted, weighed, and their orbital periods measured, now number over 500 for the nearest hundred stars. Several of these indicate promising conditions for the existence of life and naturally are among the early objectives of the interstellar probes.

That the former mystery of the black holes has been cleared up is old news of course. But that their sizes and distribution are now almost completely catalogued for this galaxy is a matter of great scientific importance. Using this information in combination with other data, the

new cosmology has shown conclusively that a portion of the universe must have existed prior to the Big Bang. To many cosmologists this result came as a great surprise. Another scientific conclusion that now appears to be certain is that half of the galaxies are made up of anti-matter. In particular, our nearest galactic neighbor, Andromeda, is one of the anti-matter ones and therefore intrinsically forbids our presence. The theory of formation and preservation of the anti-matter galaxies was one of the vital keys of the new cosmology.

In addition to these space spectaculars the scientific developments of this century--which by now cannot be separated from space science--have led to the brilliant technological achievements in the maintenance of human health--in adapting to the space environment as well as the earth's surface. Thanks to this progress, the 20th century (and prior) concepts involving fears of death are not much more than a lingering memory. Death today is almost always a natural, pleasant and usually voluntary experience which occurs when the time is ripe.

A full catalogue of achievements over the last hundred years would take volumes just to record those of greatest importance. In every field of basic science there has been at least one fundamental revolution in understanding. In applied sciences there have occurred thousands of breakthroughs which have led to weather control, inexpensive energy, pristine environments, supermaterials, and now the era of superrobots, without which there might be little time left for politicking and complaints.

One of the interesting experiences for children today is that of visiting the reconstructed Bicentennial village in which the way of life of our ancestors is accurately replicated. They always find it astonishing

in their first visit. Noisy gasoline engines, vacuum cleaners, pot-holed roads, record players, oil-burning furnaces, incandescent lamps, trash cans, fire stations, and movie houses are all novel--and to them astonishingly "primitive."

I have been dwelling upon past scientific progress, but what of the future? In pure science we simply cannot even guess; it is the discovery of that which before was not known. However, in applied science or technology we can make some guesses. Here are a few:

Genetics: a complete unraveling and understanding of the life process of human beings. That is, from the DNA sequence a complete prescription of any growth process through sequential cell divisions and specialization.

Materials: The ultimate materials for use in functional design to achieve optimum strength, flexibility, geometry, and corrosive resistance will be achieved in 10,000 or more materials. Also materials superconductive at the maximum temperature theoretically possible (260°K) will be created.

Computers: The theoretical limit to operational speed and information transfer, unlimited ultra-high-density memory, reliability greater than that from external "freak" accidents, automatic programming and voice communications will all be achieved.

Robots: Which can do anything mechanical that man does first and wants the robot to repeat--and more. Intelligent robots will be created that can learn in most of the ways in which humans do--but much more rapidly.

Space development: Large human colonies will be able to travel anywhere in the solar system and will be self-sufficient for at least 20 years, perhaps indefinitely. Cost of space transportation will fall by

a factor of 10 or more. At least 100 million people will have their homes in space colonies.

One of the socio-political consequences of the above developments is that human beings in space colonies, whether in orbit or on a planetary surface such as the moon or Mars, probably will become independent of earth--that is, they will become sovereign in the sense of nations on earth. Most sociologists today believe that this is an inevitable result in space--just as it has been on earth. I can only assume that these natives will be friendly--if we are.

Chapter VII

REVIEW AND ASSESSMENT

A. Images of the Future

Let us first review briefly what has been attempted in the first six chapters. The first chapter offers a typology of various space scenarios and of various themes for constructing scenarios. The point is made that such scenarios have many uses, and that from NASA's viewpoint an important, if somewhat neglected, one is the systematic formulation and dissemination of appropriate images of the future. Hopefully these images would be realistically developed and become valuable to policymakers.

We believe that NASA should try, in a low-keyed manner, to formulate and promulgate a concept of future space development as part of the manifest destiny of humanity, and as an obvious next phase in an historical process which started in the 15th century with the age of exploration and which has led to today's modern world.

In the 19th century many Americans overtly believed in manifest destiny, a concept which encouraged the opening up of the West and extended this country to the Pacific. Through our scenarios we did find that space, to a rather remarkable degree, was likely to play roles similar to those which the frontier played in America's past. According to some historians, such as Frederick J. Turner, much of the character of American life--the egalitarianism, the feelings of independence and competence, the sense of openness and unlimited vistas, the upward mobility, and a deep belief in democracy seem to have been dependent on, or strongly influenced by, the existence of a frontier. We believe that this characteristic of our past

may well be continued--possibly in a modified or weaker form--through the exploration, development and exploitation of space.

Whether the analogy is valid or not, an accepted image of the future can give rise to expectations that could materialize into real space projects. We also argued that for such images to have the greatest near-term impact in the U.S. they should emphasize the practical uses of space--i.e., its scientific and economic values--and should treat its important psychological, political, social, and cultural consequences as by-products.

We believe that basic images of the future such as we have presented in this report are generally unavailable in America, or elsewhere. It is clear there is a large and active group of science fiction fans and it is clear that publicists have been very instrumental in spreading particular concepts (such as Professor O'Neill, for space colonies). But much more can be done. Many potential space activities, even if they are unduly optimistic or exaggerated (for example, as some critics believe Professor O'Neill's estimates to be), are still useful as part of a social process. If supported by NASA they should be properly formulated and labeled. NASA should also furnish long-range estimates and images of the future which are more or less consonant with its official positions; these can be quite exciting and still be plausible, or even conservative, within NASA.

The authors believe that a basis exists for a popular but serious book that will reflect much of the material in this report. We believe our activity has been a very useful one, even though that is clearly a self-serving remark. However, we would not have entered this project unless we felt that it was useful from a broad national perspective. Enough is now happening in space to guarantee a moderate level of future activity.

This means that whatever unexpected treasures are yet to be found have some reasonable probability of being discovered even in a pessimistic context. We should add that the spirit and need of scientific inquiry, and the spirit and need for exploration, will remain as permanent forces which create varying pressures for some kind of activity almost everywhere--and in most of our scenarios these needs and pressures increase--if not in the United States then elsewhere.

B. Earth-Centered Perspective

In Chapter II we try to visualize the coming economic role of space developments in an earth-centered perspective. Our view lies between that of the more extreme space enthusiasts who feel that society's problems on earth are basically intractable and should not be allowed to hinder the future of space, and those who conceive of the space potential as very limited, and often as an activity to enthrall the young or the technostucture--and thus often a place for expensive, sterile, dangerous or foolish exploits.

We first offer evidence that the basic physical problems relating to the world's future needs can, in principle, be solved without recourse to outer space, that the earth has more than enough resources to supply an adequate standard of living for all. On the other hand it seems quite clear that cis-lunar space and possibly the rest of the solar system could turn out to be extraordinarily important in an economic and technological sense. This outcome appears to follow from just the current reasonably projected potential in space--that is, without having to conjure up unforeseeable great breakthroughs. Of course it also seems to be reasonable

to expect that future space development will yield some equivalents of Middle East oil or Klondike gold--that is, vast treasures which have not yet been dreamed of. Thus, it is almost certain that space exploration will lead to great benefits, and possibly to an extraordinary economic and technological impact.

In our basic Surprise-Free Earth-Centered Scenario we concluded that good long-term prospects existed for technological solutions to current concerns about the adequacy of the world's physical resources--although social and political problems could--and probably will--create many difficulties in applying such solutions. When potential space developments are added to the above scenario the outlook for the required solutions is further brightened. That is, over time space technology and spinoffs from it will certainly contribute to these solutions--perhaps enormously. With our necessarily poor vision into the future we can still list a few general ways in which space activities are likely to contribute. In each category below we include spinoffs and serendipities, since they are often the most productive, although intrinsically obscure, avenues:

- Energy: 1) Space-based electric power stations
2) LANDSAT information for oil and gas exploration
3) Spinoffs and serendipities

- Materials: 1) Superior materials from unique processing capabilities in space industries
2) Lunar and asteroidal sources of minerals
3) LANDSAT assistance in mineral exploration on earth
4) Spinoffs and serendipities

- Food & Water: 1) Improving weather forecasts for days, weeks, months, and possibly over longer intervals
2) LANDSAT information on crops, disease, insects, water, etc.
3) Spinoffs and serendipities

- Environment:
- 1) Monitoring pollutants by satellites
 - 2) LANDSAT information on environment and land use
 - 3) Processing in space (e.g., nuclear power or other radioactive processes)
 - 4) Spinoffs and serendipities

The economic and technological potential of space leads us "paradoxically" to conclude that the near-term "soft," or socio-psychological, effects may equal or outweigh the "hard" returns. As an analogous example, it might seem wise for the United States to devote, say, 1 percent of its GNP to building "pyramids" and "cathedrals" in order to improve public morale and national unity. However, a direct attempt toward this end would almost certainly be doomed to failure. In our culture it is also vital for most "grandeur-creating" projects to be economically sensible--otherwise the average citizen will reject them. No great national interest exists in "climbing mountains because they are there." Most Americans have to feel that a practical, scientific, military, economic or other purpose is served in "climbing mountains" before they will support and take pride in such activities. Isolated events may be exciting--and create temporary heroes--but a deep lasting pride and a solid sense of achievement usually require practical projects.

So many tangible economic and scientific opportunities do exist in outer space that the country can afford to pursue them with intensity--and also reap the important psychological, political, social and cultural benefits as "by-products" of the main effort. In a cost-benefit analysis the space projects cannot be given explicit credit for such "by-products," but it can note the potential which exists. It should be made clear that these "by-products" could be as valuable as the more tangible objectives, including any windfalls. That would be our judgment, at least for the balance of this century.

C. Space Technology

Chapter III explores some of the technology expected to be associated with space in the near, medium and long term. Some readers may find this chapter exciting because the technological possibilities portrayed are greater than many relatively knowledgeable groups currently seem to understand. This chapter indicates that a basic change in the character of our practical activities in space is likely to occur by the late '80s or early '90s. As knowledgeable NASA personnel and other space-oriented professionals know, up until now space systems have attempted to keep the large, complex, expensive equipment on the ground, where possible, and place the smaller or cheaper equipment into space. (The present situation may be compared to the use of river ferries which are severely limited in the loads they can transport.) In ten or fifteen years, we expect to find many new systems which deploy the large complex equipment in space and keep the small inexpensive, but numerous, parts of the system on the ground. (To continue the analogy this change would be similar to the replacement of most river ferries with modern bridges. That change was basic and effective.)

Although Chapter III focuses strongly on technology, it also attempts to indicate that future developments in space, especially in terms of manned activities, are probably dependent more on a number of imponderables other than successful technology. For example, the personal health and safety of a space traveler--or tourist--is potentially crucial to many activities. Although safety is more or less a direct consequence of technology, future health in space is still a mystery which may involve risks that are subject to straightforward technological solution--or at least not for quite a long

time. At the moment there appears to be some useful information from prior life science studies, but these are reliable mainly for relatively short-term exposures to the space environment.

Space tourism, which appears in every scenario as a major new growth industry, should not be taken as quite that certain. That is, even assuming that problems of health, safety and cost do not become intrinsic deterrents, it is possible at least to conceive of other developments that might hamper that potential industry. For example, the excitement might vanish after the first few years. After all, will there be enough important experiences which an expensive tour can bring that the advanced electronic systems anticipated for the 21st century could not? Many of the visual experiences in space might be better perceived through electronics, and probably a lot more comfortably. Still, the experience of weightlessness, or the knowledge of the new realities, such as being suspended in space, perhaps 25,000 miles above the earth, or a chance to walk on the moon, might prove to be priceless. Certainly electronics has not been a sufficient substitute to date. These uncertainties might possibly be resolved fully during this century.

Another consideration might be that of the possible fragility of the upper atmosphere. If it is found that this protective envelope would be seriously degraded beyond some calculated number of annual launches, then the future tourist industry could be greatly hampered since it would probably have a relatively low priority. This might not rule tourism out but could limit it severely or restrict it to only a very few high priority needs. On the other hand, the upper atmosphere might not prove to be fragile at all for properly designed propulsive systems.

These potential issues are raised for balance in this discussion. Space tourism has an exciting long-term potential but it first needs to be developed and shown to yield sufficient benefits. During the next few decades unforeseen problems will undoubtedly arise and will need to be solved satisfactorily. Until that time space tours are likely to remain in the limbo of hopes or dreams.

If the health problems associated with protracted journeys into space should become relatively severe, various solutions may emerge over time that will permit space development to continue. Indeed, the major competitors to the human presence in space have been and undoubtedly will be the various automated devices--robots, in one form or another. Currently, according to Carl Sagan, "As a rule of thumb, a manned mission costs 50 to 100 times more than a comparable unmanned mission."^{*} Over time, automation has become increasingly compact and effective. That is, the robots tend to shrink in size and increase the range of their activities. Humans can learn to do the latter, but they will have difficulty in shrinking.

Nevertheless, a human presence in space will be needed and is likely to grow. The economics of the competition with the robots generally will determine the relative balance only when the same tasks can be done by both. As space development proceeds, the balance may shift either way. However, as space industrialization grows in complexity the need for human specialists may grow in proportion. The first Space Shuttle decade, the '80s, should give us some early clues about the outcome of this long-term competition.

* The New York Times Magazine, July 10, 1977.

D. The Scenarios

Optimistic Scenario: Some of the potential technology discussed in Chapter III is used in the Optimistic Scenario of Chapter IV. This scenario simply exercises the possible technological and economic muscles to show what could reasonably occur in an environment of sustained funding, high morale, dedication, cooperation, good management, and reasonable luck. It is intended to open up some vistas, to make it clear that extraordinary possibilities exist that are not necessarily Utopian. Although the events portrayed are generally not expected to happen as soon as indicated, we believe that the sequence is not intrinsically forbidden. It may only require a change in public attitudes, which is certainly possible. The scenario not only is intended to give a sense of some ultimate possibilities but also of an eventual outcome. Almost all of the technological developments that "happen" in the first 100 years are likely to occur sooner or later--even in a pessimistic scenario, although probably much later and on a reduced scale. As is discussed below, the economic and technological progress associated with the Optimistic Scenario is amazing in its long-term outcome, but is relatively modest in any particular year or decade.

Pessimistic Scenario: Chapter V portrays the two New International Order Scenarios. Part I carries out a theme which today is widely accepted in the world, although not by the authors. This is a perspective which suggests that the developed nations generally are relatively "decadent" and that the developing nations have the energy and dynamism to push them aside and become the focus of the future. The second (Part II) version of

the scenario assumes that the richer countries will, in part through the transfer of resources, greatly accelerate the development of the poorer countries and that these, as they attain comparable wealth and technological advancement, will adopt the social attitudes and ideology of their former benefactors. Both of these scenarios strike us as being relatively improbable--but they do raise important issues.

On the other hand, we do find that many formerly poor nations are now middle-income ones and progressing very rapidly. Scenario I gives special roles to China and Brazil in determining the world's future, each for different reasons. Scenario II gives a much weakened and modified form of this New International Order in which both the middle-income nations and the poor nations eventually become post-industrial, after which further economic progress is very slow.

In both scenarios, it is the middle-income nations that appear likely to "challenge" the lead of the U.S. and the Soviet Union in space activities by the end of the century or soon afterwards. In fact, in these scenarios the U.S. lead--as measured by budgets--is lost to both the Russians and the Chinese before the year 2000, and to the Brazilians soon afterwards. We believe that in this respect the two scenarios depicted are not implausible; it may well turn out that these newcomers in advanced technology and growing affluence will become technologically dominant, including space development. Perhaps nothing succeeds like success in a space "race." Moreover, the successes of the former middle-income countries in space could greatly increase their ability to become wealthier than the present developed nations. In these scenarios it occurs, not only because of

direct economic and technological achievements, but because their success creates a high morale and a sense of competence from the attainment of communal goals--attitudes that growing space activities might also engender in the OECD nations under appropriate circumstances.

Because visible signs of success are so important, many of the Third World countries often attempt to "fake" them. That is, they are attracted to four-lane highways and jet airliners in order to achieve the appearance of success before they have properly attended to their problems in rural roads, agriculture, employment, and education. The diversion of resources to showy projects can be tragic even if the showy projects are successful; usually they are not. Thus it may be undesirable for a Third World country to jump into space development rapidly. Unless both their economies and technological resources are substantial it can represent a serious and impractical diversion of scarce resources. However, the appropriate economic conditions and technological development can appear with astonishing rapidity. In fact, even S. Korea and Taiwan may be ready for certain specialized space ventures in the foreseeable future because of the rapidity with which they have been progressing. Potential economic and technological giants such as China and Brazil may also develop a space capability much more quickly than generally expected, if their recent progress continues.

In our most Pessimistic Scenario progress in economics and technology becomes very slow after a country becomes post-industrial. Still, a surprising outcome (one which struck both authors forcibly) was that eventually, despite a general pessimism about space projects and other technological developments, space activities still become surprisingly extensive.

(Consider, as an analogy, that even if Queen Isabella had not financed Columbus, or if he had failed on his voyage, the Western Hemisphere would still be there, waiting to be found; since the time was ripe for worldwide exploration and exploitation other Europeans would have reached it before many more years had passed.)

The pressures for exploring and exploiting outer space basically derive from increasing wealth and advancing technologies. Over time the projects become easier to fund and, with advances in technology, less difficult to do. At some appropriate time, barring an almost religious aversion to new technology, a sufficient desire for space development will arise--even if long intervals occur when support is hard to find.

Another analogy might be made with the development of the U.S. railroads and the West. The railroads were stimulated by gifts of free land by the government and the belief that, as the railroads were built, the traffic would follow--that a great deal of industrial mining and agricultural development, including forestry, would occur quite rapidly and justify their investment. The time was ripe and it did.

A similar experience could occur with the Space Shuttle system. In space there may be no equivalent to the free 160-acre homesteads which were once available to the average American, but great opportunities are likely to exist for various "railroad" companies who "stake out claims" in outer space. At the moment the space frontier and its available resources seem relatively unlimited. Relatively few critical regions appear to exist that might eventually become the cause of major conflicts and hinder commercial development.

Moderate Scenario: Chapter VI develops our Moderate Scenario which is intended to be more plausible than the others. It has an implied conviction that the progress represented is worth striving for--and can be achieved without undue reaching. It represents our "median" image of future developments in space. It contains some fictional elements which are intended to be prototypes of actual historical events, including individuals who are "movers" and "shakers" and who play central roles in forcing a more rapid space development.

The Moderate Scenario emphasizes two new commercial opportunities: space industrialization and tourism, both of which appear to have extremely large potential in all the scenarios. The term, "space tourism" alone may not convey the intended meaning. If we assume that space travel is the moving experience that it has been to many astronauts, at some future time various organizations or societies may wish to provide this experience to selected people. It may be a reward for dedicated service or special contributions, or a ritual associated with special religious groups. Or it could be arranged through an open or limited access lottery.

Shortly after the beginning of space tourism, assuming it is successful, we find the possibility of great interest in establishing permanent orbiting colonies--possibly with many of the same motivations. We have not dwelt upon the desire for utopias or choices for one's preferred life style. However, it may well turn out that one of the major motivations for colonies in space is similar to that which drove the Pilgrims to New England: the desire to choose their way of life with minimal interference from the home country. This outcome, of course, would depend very much on

the cost and viability of such colonies. But even relatively small sects, given a growing future affluence, could eventually finance a colony if they were sufficiently motivated--particularly if they had ability to tithe, like the Mormons or Black Muslims.*

In many religions the wealth of the church is thought of as a common resource for its members to help those in difficulties and sometimes, even when some members are successful, to be used to facilitate additional success. To the extent that space colonies, in addition to their religious connotation, might look like profitable ventures then the investments would eventually increase the wealth of the church. Furthermore, through merit criteria or lotteries, every member would have a chance to become a colonist, or a tourist. The church might deem the high costs well worth the increased faith and activity of its members--particularly if these "tourists" returned with an inspired and zealous commitment to the church.

E. Potential for Growth

Our very rough estimate of current world space project expenditures is about \$9-billion per year on non-military developments and perhaps half that much on military space programs. That is, total expenditures on space projects are about .2 percent of the GWP (about .13 percent non-military, and .07 percent military).

In a pessimistic space scenario that small (.13 percent) fraction generally remains stable or decreases, despite the fact that the cost of transportation to space must almost certainly fall by more than a factor

* For example, if 1,000,000 families each contributed \$2,500 a year for 40 years, without interest this becomes \$100 billion, enough to establish a substantial colony in the early to mid-21st century, according to our projections. The contributions could appear to a believer as a tax-exempt investment in the future rather than as a gift.

On the positive side--that is, from a space enthusiast's point of view--the high growth rates lead to an optimistic scenario. In the Optimistic Scenario of Chapter IV the average growth rate in worldwide space investments rose during the last quarter of the 20th century at about 10-percent per annum (about the average for a "glamour" or high technology industry currently). During the first 100 years after a brief rise to a 12-percent growth rate, the Gross Space Product (GSP) then declined steadily to about an 8-percent growth rate, and during the second 100 years to 5 percent--see Table 17, p. 167. We note that the growth rate in space, per capita, ends at about 2-1/2 percent--actually, less than the productivity increase of the average American worker in recent decades. Thus, the Optimistic Scenario portrayed would not be perceived as having an astonishing growth during any year of its history--except perhaps during 1980-2000, when a general change in societal attitudes toward space is assumed to occur. After the turn of the century it is just the assumed long-term steadiness of the slowly declining growth rate that brings about a "miraculous" transformation--first to a \$30-trillion GSP and then, during the much slower growth of the second 100 years, to an awesome \$12,000 trillion (Table 17). Stated only in this last way the numbers tend to be hard to accept as having any reality; the average annual GWP/capita, including the GSPs after 200 years, reaches almost \$1 million--about 600 times greater than the average today!

The 200-year progression of moderate successes in the Optimistic Scenario not only leads to fantastic developments in space, it also demands an extremely rich society on earth--one in which essentially everyone (except those who voluntarily opt out) is an active participant. To the

of 10 during the next century. Still the GWP during the next 100 years is expected--in our earth-centered surprise-free projections--to rise by about a factor of 20 (Table 1, p. 40). If space expenditures merely keep pace with GWP they would be approximately \$200-\$300 billion by then and would almost double again in the following 100-year period. The "truly" pessimistic space scenario would, on average, maintain a slower growth in space investments than the GWP. On average means that "temporary" fluctuations may vary that projection somewhat over periods of a few decades or less.

A moderate scenario, in our view, would, on average, but probably with erratic fluctuations, show a growth rate in space which exceeds that on earth--perhaps by about a factor of 2 or 3. Thus, the world's space budget would have a mean growth rate of 3-1/2 percent to 5 percent, which would lead to space budgets between \$200 and \$1,200 billion at the Tricentennial. We arrived at \$700 billion for our particular Moderate Scenario (Chapter VI).

However, we notice that the 2076 budget (or annual investment) estimate is extremely sensitive to the assumed average growth rate. Over a hundred years a 2-percent change in this average affects the budget by about a factor of 7--and, over 200 years, by a factor of 50. Yet it appears to us that the inherent uncertainty in the average future growth rate is intrinsically greater than 2 percent and may be as high as 5 percent--the latter leads to a factor of more than 100 over a century and more than an astonishing 10,000 over two centuries!

average citizen, today, this must represent an unbelievable outcome--even though the path to it is relatively straightforward. For example, to go from the current GWP of roughly \$6.6 trillion to one of \$6,700 trillion over 200 years (on earth, see Table 17), requires "only" an average growth rate of 3.5 percent--less than that which the world as a whole has experienced during the last few decades! What is so astonishing about that? The answer appears to be nothing to an optimist, everything to a pessimist.

In the above sense of economic and technological progress, we have portrayed pessimistic, moderate, and optimistic scenarios. In the pessimistic one the intrinsically high-technology enterprises are treated as fascinating but dangerous tools to be kept under very tight control. Society responds to science and technology as if it were a "foreign" culture beyond its real understanding, and potentially fraught with great new risks.

The Moderate Scenario is more of a long-term business-as-usual perspective. Where space projects are profitable the economic rewards tend, over time, to dominate the socio-political restraints and, accompanied by numerous problems, difficulties and interruptions, space development erratically but slowly climbs the ladder of progress. But even such erratic slow progress over a "mere" 100 years brings about changes which in today's world could only seem amazing--for example, a \$600-billion annual investment in space when transport costs are about 1/25 of the present ones, coupled with tremendous advances (to take a few examples) in automation, instruments, materials, and new designs (for vehicles, industries, communication systems, and processes in space). Thus, even

the slow, erratic Moderate Scenario reveals a potentially astounding transformation, one that may be almost impossible to comprehend fully or foresee accurately: That is, the projections we have made are likely to appear primitive 100 years from now--just as do the U.S. projections from 100 years ago that could not seriously imagine the general use of automobiles, let alone airliners, space flight, electronic computers, television, or nuclear energy--to name just a few of the evolved "miracles"--and all this with an average growth in per capita GNP of less than 2 percent.

How then, when the business-as-usual projection becomes shocking or incomprehensible, can we expect anything but incredulous reactions for any optimistic scenario? Our Optimistic Scenario requires, for the world as a whole, merely that human beings opt for growth and set about to obtain it with roughly the same, but sustained, vigor that on average we find exists today. That is all.

LIST OF ACRONYMS

ANC: Anti-Nuclear Command	NASA: National Aeronautics and Space Administration
CCD: charge-coupled device	NATO: North Atlantic Treaty Organization
COMSAT: Communications Satellite	NEO: near-earth orbit
DNA: deoxyribonucleic acid	NIMBUS: NASA Improved Meteorological Satellite
EFF: efficiency	OECD: Organization for Economic Cooperation and Development
E-M: electro-magnetic	OFS: Outlook for Space
ERTS: Earth Resources Technology Satellite	OPEC: Organization of Petroleum Exporting Countries
ESA: European Space Agency	
G: gravity	QOL: quality of life
GHZ: gigahertz	
GNP: Gross National Product	RAD: radian
GSI: Gross Space Investment	R&D: Research and Development
GSO: geosynchronous orbit	
GSP: Gross Space Product	SEASAT: Sea Observation Satellite
GWP: Gross World Product	SEP: solar electric power
	SEPS: Solar Electric Power System
HEAO: High Energy Astronomical Observatory	SI: Space Industrialization
HLLV: Heavy Lift Launch Vehicle	SMM: Solar Maximum Mission
HYV: high-yield variety	SSI: Solar Systems, Incorporated
	SSPS: Solar Satellite Power System
INTELSAT: International Telecom- munications Satellite Organization	SSTO: Single State To Orbit
IPES: Interplanetary Exploration Society	SSUS: Spinning Solid Upper Stage
ISDS: International Space Defense System	STS: Space Transportation System
IUS: Interim Upper Stage	
K.E.V.: thousand electron volts	TIROS: Television Infrared Observa- tion Satellite
	TWACA: Temporary World Arms Control Agency
LANDSAT: Land Satellite	TWDA: Temporary World Defense Authority
LEO: low-earth orbit	
	ULA: United Lunar Authority
MBPD: million barrels per day	
MISS: Made In a Space Station	VTOVL: Vertical Take Off and Vertical Landing
MPD: magnetoplasmodynamic	

BIBLIOGRAPHY

- Bekey, I., Mayer, H.L. and Wolfe, M.G. Advanced Space System Concepts and Their Orbital Support Needs (1980-2000). Volume I: Executive Summary. ART-76(7365)-I, Vol. I. Volume III: Detailed Data - Part I: Catalog of Initiatives, Functional Options, and Future Environments and Goals, ATR-76(7365)-I, Vol. III, El Segundo, California: The Aerospace Corporation, April 1976.
- Bell, Daniel. The Coming of Post-Industrial Society; A Venture in Social Forecasting. New York: Basic Books, 1973.
- Bethell, Tom. "NASA (That's Right, NASA) Is A Good Thing." The Washington Monthly, November 1975, pp. 5-14.
- Brobst, Donald A. and Pratt, Walden P., eds. United States Mineral Resources. U.S. Geological Survey Professional Paper 820. Washington, D. C.: U.S. Government Printing Office, 1973.
- Brown, William M. "100,000 Quads of Natural Gas?" HI-2451/3-P. Croton-on-Hudson, N.Y.: Hudson Institute, October 1976.
- Coale, Ansley J. "The History of the Human Population." Scientific American. September 1974.
- Drake, Michael. Historical Demography: Problems and Projects. Milton Keynes, Great Britain: Open University Press, 1974.
- Drucker, Peter. The Age of Discontinuity. New York: Harper & Row, 1969.
- Ford Foundation Energy Policy Project. Exploring Energy Choices: A Preliminary Report. Washington, D. C., 1974.
- Goeller, H.E., and Weinberg, Alvin M. "The Age of Substitutability." Science, February 20, 1976.
- Kahn, Herman. "On Studying the Future." In Handbook of Political Science, Volume 7: Strategies of Inquiry, pp. 405-442. Edited by Fred I. Greenstein and Nelson W. Polsby. Reading, Massachusetts: Addison-Wesley Publishing Company, 1975.
- Kahn, Herman and Brown, William M., et al. The Next 200 Years in Space (NASA Bicentennial Planning). HI-2352-RR. Croton-on-Hudson, N.Y.: Hudson Institute, October 23, 1975.
- Kahn, Herman, Brown, William and Martel, Leon. The Next 200 Years: A Scenario for America and the World. New York: William Morrow and Company, Inc., 1976.
- Marx, Leo. The Machine in the Garden: Technology and the Pastoral Ideal in America. New York: Oxford University Press, 1964.

- Meadows, Donella H., et al. The Limits to Growth. New York: Universe Books, 1972.
- National Academy of Sciences. Practical Applications of Space Systems. 1974 Summer Study. Washington, D. C., 1975.
- National Aeronautics and Space Administration. A Forecast of Space Technology, 1980-2000. SP-387. Washington, D. C.: Scientific and Technical Information Office, January 1976.
- _____. Outlook for Space. SP-386. Washington, D. C.: Scientific and Technical Information Office, January 1976.
- _____. Lunar Utilization. Abstracts of Papers Presented at a Special Session of the Seventh Annual Lunar Science Conference, 16 March 1976. Sponsored by the National Aeronautics and Space Administration. Houston, Texas: Lunar Science Institute, 1976.
- _____. Proceedings, Third Space Processing Symposium: Skylab Results. April 30-May 1, 1974. Marshall Space Flight Center, Alabama.
- _____. Proceedings, AIAA/MSFC Symposium on Space Industrialization. May 26, 27, 1976. Marshall Space Flight Center, Alabama.
- _____. The Proceedings of the Skylab Life Sciences Symposium. August 27-29, 1974. Houston, Texas: Johnson Space Center, November 1974.
- O'Neill, Gerard K. The High Frontier: Human Colonies in Space. New York: William Morrow and Company, Inc., 1977.
- Ridpath, Ian. Worlds Beyond: A Report on the Search for Life in Space. New York: Harper & Row, 1976.
- Rockwell International, Space Division. Space Industrialization. Final, Part I: Technical Report. SD 77-AP-0076. Rockwell International, July 15, 1977.
- Skinner, B.F. Beyond Freedom and Dignity. New York: Alfred A. Knopf, Inc., 1971.
- _____. Walden Two. New York: The Macmillan Company, 1948; reprint ed., New York: Macmillan Paperbacks, 1962.
- Stine, G. Harry. The Third Industrial Revolution. New York: G.P. Putnam & Sons, 1975.
- U.S. Congress. House. Committee on Science and Technology. Future Space Programs 1975. A Compilation of Papers prepared for the Subcommittee on Space Science and Applications. 94th Cong., 1st sess., September 1975. Committee Print, 2.

- _____. "Oil Shale--An Ace in the Hole for National Security," by P.A. Petzrick. In Synthetic Fuel Loan Guarantees, Hearings Before the Committee on Science and Technology on H.R. 12112, 94th Cong. 2nd sess. 1976 [No. 56]. Appendices 2: 586-587.
- Uttal, Bro. "I.B.M. Reaches for a Golden Future in the Heavens." Fortune, June 1977.
- von Puttkamer, Jesco. "Developing Space Occupancy: Perspectives on NASA Future Space Programme Planning." Journal of the British Interplanetary Society 29 (1976).
- _____. On Man's Role in Space: A Review of Potential Utilitarian and Humanistic Benefits of Manned Space Flight. Washington, D. C.: Aeronautics and Space Administration, Office of Space Flight, December 1974.
- The Wall Street Journal. "Business and 'The New Class'." 19 May 1975, p. 8.

Appendix A*

THE NEW CLASS

For some time it has been recognized by a number of futurologists and others who speculate about social trends, that for a wealthy country the marginal utility of increased wealth could decrease quite rapidly. A decade or more ago it was widely accepted that within the next hundred years the desire for increased wealth could decrease to the point where it would strongly affect the growth rates. Almost nobody expected this effect to be felt in the very near future, although many now believe that it has begun. In particular, it has shown up in changed attitudes which strongly support the New Emphases which are listed below:

RECENT NEW EMPHASES (ALL LEADING TO "SOCIAL LIMITS TO GROWTH")

1. RISK AVERSION
2. LOCALISM
3. COMFORT, SAFETY, LEISURE AND HEALTH
4. PROTECTION OF ENVIRONMENT AND ECOLOGY
5. LOSS OF NERVE, WILL, OPTIMISM, CONFIDENCE, AND MORALE
6. PUBLIC WELFARE AND SOCIAL JUSTICE (INCLUDING EQUALITY OF RESULT)
7. HAPPINESS AND HEDONISM
8. GENERAL ANTI-TECHNOLOGY, ANTI-ECONOMIC DEVELOPMENT, ANTI-MIDDLE-CLASS ATTITUDES (E.G., "SMALL IS BETTER" AND "LIMITS-TO-GROWTH" MOVEMENTS)
9. MANY MODERN FAMILY VALUES
10. GENERAL DE-EMPHASIS OF (OR EVEN HOSTILITY TO) THE THIRTEEN TRADITIONAL LEVERS
11. INCREASING SOCIAL CONTROL AND "OVERALL PLANNING" OF THE ECONOMY OF THE "WRONG" SORT
12. ADVERSARY REGULATORY ATTITUDES
13. INNER SPACE (OMPHALOSKEPSIS) AND/OR CONCERN WITH SELF GENERALLY, PERHAPS EVEN AN EMPHASIS ON MYSTIC OR TRANSCENDENTAL VALUES

* This Appendix draws on previously published material by B. Bruce-Briggs and Herman Kahn.

If the attitudes represented in the list should become completely and intensely pervasive, it could effectively impede advancing technology in general and space development, in particular. Therefore, it is worth discussing some of the forces that give rise to the above New Emphases. First and most important: as the membership of the upper-middle class increases and as the availability of cheap, inexpensive services decreases, the upper-middle class finds that its pleasures, its privileges, its purposes, its quality of life and even its standard of living are seriously threatened. Recent books have discussed these phenomena in some detail though, perhaps, from a somewhat misleading perspective. That is, the issue is discussed as if the perspective and interests of the upper-middle class were the same as everyone else's. Little recognition is given to the fact that a middle-class individual who moves into the upper-middle class feels a substantial improvement in his standard of living and his quality of life, even if those already in the upper-middle class feel they have lost something.

Within this upper-middle class we find an active sub-group which seems to be--intellectually, politically, and polemically--a cutting edge of this phenomenon and which has been labeled the New Class. Largely these are people whose status and occupation not only derive from possession of considerable education, but who earn their living thereby--i.e., by the use of language and analytical skills. The New Class comprises a large part of academia, the media, and most "public interest" groups, and many philanthropic, public service, and social service organizations--all of which not only have been growing in size, but gaining in importance and power in the industrial Western countries and in Japan. While

there are many "gray areas" in these categories, it is also true of previously recognized classes; it is equally tough to delineate "aristocracy," "bourgeoisie," and "proletariat" with great precision, and each of these classes contains important sub-classes and new arrivals or dropouts.

Initial analysis suggests that the New Class can be defined in terms of high or potentially high (i.e. including students) formal education, professional occupational status, with an emphasis on the "soft" sciences and arts, high (but not the highest) income, usually from non-market sources (government or non-profit salaries, grants, and contracts), and relative youth. The last is important; because the New Class is "emerging" its attributes should be most obvious among the young. In this connection, Karl Marx's insight that a class does not exist unless it has self-awareness is illuminating. This kind of consciousness has appeared only recently among members of the New Class. Some intellectuals and bureaucrats have always behaved like the New Class, but perhaps only within the past decade have they had sufficient numbers to achieve the critical mass to break out of subordination to other groups and strike out on their own.

A case can be made that the New Class largely controls or dominates the following groups and institutions: the humanities and social science faculties of almost all prestige and many state universities, professional schools, and teachers colleges; most of the national media organizations--the prestigious daily newspapers, much of the periodical press, the book publishing industry, the commercial television networks, recording, films, and most educational media; the fine arts; the establishment foundations and other non-profit eleemosynary institutions concerned with influencing

public opinion; research organizations; a good part of congressional staff; the federal social welfare bureaucracy; and the government regulatory apparatus. Furthermore, New Class values and sensibilities are tending to penetrate: natural science faculties; business schools; rank and file school teachers; state and local government bureaucracies; the clergy; advertising; trade union staff; salaried professionals of all kinds; and even business corporations, especially in public relations, long-range planning, and internal education programs. These disparate groups have this in common: they are in staff (as contrasted to "line" or substantive) positions, and they produce or deal in ideas or words, holding their jobs because of analytical and literary skills usually obtained through formal education. Thus we do not think of the chief executive officers of these organizations as necessarily being of the New Class. The words "largely controls or dominates" imply that the New Class sets the basic tone of the organization and its basic policies with regard to the information it deals with, but this need not apply to the commercial and administrative aspects of the operation.

Most analysts concerned with the future of the advanced nations believe that these "brain workers" will become even more important in the next century and will play central roles in influencing the general milieu in which space projects will be undertaken. We append a series of more or less self-explanatory charts which will give the interested reader a synoptic overview of the characteristics and issues currently associated with the New Class.

We believe that this phenomenon of the New Class is quite real and that it might play a very important role in the future of space development--as some of our scenarios and socio-political contexts attempt to suggest.

ISSUES

- A. ORIGINS OF PRIVILEGED RADICALISM
ADVERSARY CULTURE
LIBERAL ETHOS
- B. CONCERN WITH COMPETENCE OF SOCIETY, ECONOMY, AND
GOVERNMENT
- C. WIDESPREAD BELIEF THAT BRAIN WORKERS WILL BE DOMINANT
CLASS OF FUTURE

BACKGROUND OF THE IDEA OF THE NEW CLASS

- 1. NEED TO DEFINE AND EXPLAIN GROUPS WITH "POWER WITHOUT
PROPERTY"
- 2. TERM "NEW CLASS" EMPLOYED IN 1956 BY MILOVAN DJILAS TO
LABEL COMMUNIST RULERS
- 3. TERM FIRST APPLIED TO U.S. BY DAVID T. BAZELON IN 1967
- 4. TERM USED IN "RIGHT" SENSE BY D.P. MOYNIHAN AND NORMAN
PODHORETZ IN 1972. CIRCULATED BY IRVING KRISTOL.

TWO DEFINITIONS OF THE NEW CLASS

"LEFT"

INCLUDES ALMOST ALL RESPONSIBLE
WHITE COLLAR WORKERS, INCLUDING
ENGINEERS AND CORPORATE
MANAGERS.

"RIGHT"

EXCLUDES "LINE" OFFICIALS
AND PRACTICAL BRAIN WORKERS
AND INCLUDES PUBLIC SECTOR
ENTREPRENEURS.

Business and 'The New Class'

By IRVING KRISTOL

Everyone wants to be loved, and it always comes as a shock to discover that there are people who dislike you for what you really are rather than for what they mistakenly think you are. Indeed, most of us desperately resist such a conclusion. We keep insisting, to ourselves and others, that those people out there who are saying nasty things about us are merely ill-informed, or misguided, or have been seduced by mischievous propaganda on the part of a handful of irredeemably perverse spirits. And we remain confident, in our heart of hearts, that if they only understood us better, they would certainly dislike us less.

In this respect businessmen are as human—and are as capable of self-deception—as anyone else. On any single day, all over the country, there are gatherings of corporate executives in which bewilderment and vexation is expressed at the climate of hostility toward business to be found in Washington, or in the media, or in academia—or even, incredibly, among their own children. And, quickly enough, the idea is born that something ought to be done to create a better understanding (and, of course, appreciation) of "the free enterprise system." A television series on economics and business for the high schools? Space advertising in the print media? Face-to-face encounters between businessman and college students? Long and serious luncheons with the editors of major newspapers and newsmagazines? In the end, many of these ideas come to fruition, at substantial costs in money and time—but with depressingly small effect.

Now, I do not wish to seem to be underestimating the degree of ignorance about business and economics which does in fact exist in the United States today. It is indeed amazing that, in a society in which business plays so crucial a role, so many people come to understand so little about it—and, at the same time, to know so much about it which isn't so. We have, for instance, managed to produce a generation of young people which, for all the education lavished on it, knows less about the world of work—even the world of their fathers' work—than any previous generation in American history. They fantasize easily, disregard common observation, appear to be radically deficient in that faculty we call common sense.

A Preference for Fantasy

Nor, it must be said, are their teachers in a much better condition. The average college professor of history, sociology, literature, political science, sometimes even economics, is just as inclined to prefer fantasy over reality. On every college campus one can hear it said casually by faculty members that the drug companies are busy suppressing cures for cancer or arthritis or whatever; or that multinational corporations "really" make or unmake American foreign policy; or that "big business" actually welcomes a depression because it creates a "reserve army of the unemployed" from which it can recruit more docile workers.

So there is certainly room for all kinds of educational endeavors on the part of the business community, and I do not wish to be interpreted as in any way discouraging them. The fact that they seem so relatively ineffectual is not necessarily an argument against them. Education is at best a slow and tedious process, and that kind of education which tries to counteract a mulsive, original miseducation is even slower and more tedious. Too many businessmen confuse education with advertising, and almost unconsciously impose the short time-horizon of the latter on the former. The unit of time appropriate to the process of education is not a year but a generation.

Having said this, however, I should like to pursue the truly interesting question of why so many intelligent people manage to entertain so many absurd ideas about economics in general and business in particular. In truth, one can properly put that question in a much stronger form: Why do so many intelligent people seem determined to hold those ideas and to resist any correction of them? Such determination there must be, because mere error and ignorance are not of themselves so obdurate. When they are, it is usually because they also are an integral part of an ideology which serves some deeper passion or interest.

And the more attentively one studies the problem, the clearer it becomes that what is commonly called a "bias" or an "animus" against business is really a by-product of a larger purposiveness. There are people "out there" who find it convenient to believe the worst about business because they have certain adverse intentions toward the business community to begin with. They dislike business for what it is, not for what they mistakenly think it

Board of Contributors

There are people "out there" who find it convenient to believe the worst about business because they have certain adverse intentions toward the business community to begin with. They dislike business for what it is, not for what they mistakenly think it is.

is. These people constitute what one may simply call, for lack of a better name, "the new class."

This "new class" is not easily defined but may be vaguely described. It consists of a goodly proportion of those college-educated people whose skills and vocations proliferate in a "post-industrial society" (to use Daniel Bell's convenient term). We are talking about scientists, teachers and educational administrators, journalists and others in the communications industries, psychologists, social workers, those lawyers and doctors who make their careers in the expanding public sector, city planners, the staffs of the larger foundations, the upper levels of the government bureaucracy, etc., etc. It is, by now, a quite numerous class; it is an indispensable class for our kind of society; it is a disproportionately powerful class; it is also an ambitious and frustrated class.

Kevin Phillips calls this class "the mediocracy," in his new book of that title. Though the book has many shrewd observations, the term he chooses seems to me to be unfortunate. It helps prolong what might be called the "Agnew illusion"—i.e., that much of our troubles derive from the fact that a small and self-selected group, whose opinions are unrepresentative of the American people, have usurped control of our media and use their strategic positions to launch an assault on our traditions and institutions. Such a populist perspective is misleading and ultimately self-defeating. Members of the new class do not "control" the media, they are the media—just as

they are our educational system, our public health and welfare systems, and much else. Even if the president of CBS or the publisher of Time were to decide tomorrow that George Wallace would be the ideal President, it would have practically no effect on what is broadcast or published. These executives have as much control over "their" bureaucracies as the Secretary of HEW has over his, or as the average college president has over his faculty.

What does this "new class" want and why should it be so hostile to the business community? Well, one should understand that the members of this class are "idealist," in the 1960s sense of that term—i.e., they are not much interested in money, but are keenly interested in power. Power for what? Well, the power to shape our civilization—a power which, in a capitalist system, is supposed to reside in the free market. The "new class" wants to see much of this power redistributed to government, where they will then have a major say in how it is exercised.

From the very beginnings of capitalism, there has always existed a small group of men and women who disapproved of the pervasive influence of the free market on the civilization in which we live. One used to call this group "the Intellectuals," and they are the ancestors of our own "new class," very few of whom are intellectuals but all of whom inherit the attitudes toward capitalism that have flourished among intellectuals for more than a century-and-a-half. This attitude may accurately be called "elitist"—though people who are convinced they incarnate "the public interest," as distinct from all the private interests of a free society, are not likely to think of themselves in such a way. It is basically suspicious of, and hostile to, the market precisely because the market is so vulgarly democratic—one dollar, one vote. A civilization shaped by market transactions is a civilization responsive to the common appetites, preferences, and aspirations of common people. The "new class"—intelligent, educated, energetic—has little respect for such a commonplace civilization. It wishes to see its "ideals" more effectual than the market is likely to permit them to be. And so it tries always to supersede economics by politics—an activity in which it is most competent, since it has the talents and the implicit authority to shape public opinion on all larger issues.

Its Own Gravedigger?

So there is a sense in which capitalism may yet turn out to be its own gravedigger, since it is capitalism that creates this "new class"—through economic growth, affluence, mass higher education, the proliferation of new technologies of communi-

cation, and in a hundred other ways. Moreover, it must be said that the "idealism" of this "new class," though in all respects self-serving, is not for that reason insincere. It really is true that a civilization shaped predominantly by a free market—by the preferences and appetites of ordinary men and women—has a "quality of life" that is likely to be regarded as less than wholly admirable by the better-educated classes. To be sure, these classes could try to improve things by elevating and refining the preferences of all those ordinary people. That, supposedly, is the liberal and democratic way. But it is so much easier to mobilize the active layers of public opinion behind such issues as environmentalism, ecology, consumer protection, and economic planning, to give the governmental bureaucracy the power to regulate and coerce, and eventually to "politicize" the economic decision-making process. And this is, of course, exactly what has been happening.

There can be little doubt that if these new imperialistic impulses on the part of "the public sector" (i.e., the political sector) are unrestrained, we shall move toward some version of state capitalism in which the citizen's individual liberty would be rendered ever more insecure. But it is important not to have any illusions about how much can be done to cope with this situation. The "new class" is here, it is firmly established in its own societal sectors, and it is not going to go away. It is idle, therefore, to talk about returning to a "free enterprise" system in which government will play the modest role it used to. The idea of such a counter-reformation is utopian. Ronald Reagan was a two-term governor of California, and whatever his accomplishments, the restoration of "free enterprise" was not one of them. Were he to become a two-term President, he (and we) would find that, after the ideological smoke had cleared, not all that much had changed.

Not Hopeless, But . . .

Not that the situation is hopeless—it's just that one has to recognize the limited range of the possible. It is possible, I think, at least to preserve a substantial and vigorous private sector—not only a business sector, but also a non-governmental not-for-profit sector—in the United States. This can happen, not because of the self-evident virtues of business, but because of the profound appeal of individual liberty to all Americans, and because of the equally profound distrust of big government by all Americans. In this appeal and this distrust even members of the "new class" share, to one degree or another. It is our good fortune that they are not doctrinaire social-

ists, as in Britain, even if they sometimes look and sound like it. They have long wanted their "place in the sun," they are in the process of seizing and consolidating it—and now they have to be assimilated into the system (even as the system will have to change to assimilate them). It will be a slow and painful business, but need not end in calamity.

A good part of this process of assimilation will be the education of this "new class" in the actualities of business and economics—not their conversion to "free enterprise"—so that they can exercise their power responsibly. It will be an immense educational task, in which the business community certainly can play an important role. But before it can play this role, business has first to understand the new sociological and political reality within which it is now operating. That, too, is an educational task of no small proportions.

Mr. Kristol is Henry Luce Professor of Urban Values at New York University and co-editor of the quarterly *The Public Interest*. He is also a member of the Journal's Board of Contributors, five distinguished professors who contribute periodic articles reflecting a broad range of views.

The Wall Street Journal,
May 19, 1975. Reprinted
with permission of The
Wall Street Journal, ©
Dow Jones & Company, Inc.
(1975). All rights
reserved.

THE NEW CLASS

(POSSESSES KNOWLEDGE, LANGUAGE SKILLS, AND FORMAL EDUCATION
RATHER THAN PRIVILEGED FAMILY, PROPERTY, OR ENTREPRE-
NEURIAL SKILLS)

ACADEMICS, ESPECIALLY BUT NOT EXCLUSIVELY THE HUMANITIES
AND SOCIAL SCIENCES, AND VERY RARELY ENGINEERS AND
GEOLOGISTS

TEACHERS, ESPECIALLY NON-SCIENTISTS

SOCIAL WELFARE BUREAUCRATS

GOVERNMENT UNIONS

PROFESSIONALS, ESPECIALLY SALÁRIED

NATIONAL MEDIA

ADVERTISING

FOUNDATIONS

RESEARCH ORGANIZATIONS

GOVERNMENT STAFF

UNION STAFF

MAINSTREAM PROTESTANT CLERGY

MANY CORPORATE PLANNERS AND P.R. TYPES

PUBLIC SECTOR ENTREPRENEURS

SOME LABELS OF THE NEW CLASS

INTELLECTUALS
INTELLIGENTSIA
BRAIN WORKERS
KNOWLEDGE WORKERS
CLERISY
TECHNOSTRUCTURE
EDUCATIONAL AND SCIENTIFIC ESTATE
MERITOCRACY
MEDIACRACY

ETHNIC ORIGINS OF MOST OF NEW CLASS
(GROUPS WITH HIGH REGARD FOR EDUCATION)

OLD YANKEE ELITES, ESPECIALLY THE DECLINING EX-RICH

"MAINSTREAM" PROTESTANT DENOMINATIONS

CONGREGATIONALISTS

PRESBYTERIANS

REFORMED

QUAKERS

UNITARIANS

EPISCOPALIANS

NORTHERN METHODISTS

JEWS, ESPECIALLY REFORM AND SECULARIZED

HAUTE-EMBOURGEOISED ROMAN CATHOLICS

E.G. JESUITS

IF THERE IS AN EMERGING NEW CLASS
IT SHOULD BE IDENTIFIED BY:

HIGH FORMAL EDUCATION

RESPECTABLE SOCIAL ORIGINS

"PROFESSIONAL" OCCUPATIONAL STATUS

HIGH (BUT NOT HIGHEST) INCOME

NON-MARKET INCOME

GOVERNMENT SALARY

NON-PROFIT SALARY

CONTRACTS AND GRANTS

RELATIVE YOUTH

KEY NEW CLASS INSTITUTIONS

UNIVERSITIES
RESEARCH INSTITUTES
GOVERNMENT STAFFS
PUBLIC INTEREST LOBBYS
OTHER NON-PROFIT ORGANIZATIONS
MEDIA CONGLOMERATES

SOME "NEW CLASS" ORGANIZATIONS

ACLU
ADA
LEAGUE OF WOMEN VOTERS
NATIONAL COUNCIL OF CHURCHES
COMMON CAUSE
NADERITES
CONSUMERS UNION
SIERRA CLUB
FORD FOUNDATION

NEW CLASS ALLIES AND CO-BELLIGERENTS

DECADENT OLD RICH
MORE RADICAL TRADE UNIONS
OLD LEFT
NEW LEFT REMNANTS
MILITANT FEMINISTS
ORGANIZED MINORITY GROUPS
BLACKS
OTHER NON-WHITES
PSEUDO-ETHNICS
(LEFT) PSUEDO-POPULISTS
"TRENDIES"
THE UPPER MIDDLE CLASS IN GENERAL

h-11
0-0

A PARADIGM OF UPPER-MIDDLE-CLASS LIFESTYLES

<u>TRADITIONAL</u>	<u>EARLY INDUSTRIAL</u>	<u>MATURE INDUSTRIAL</u>
MODEST STATUS	HIGH STATUS	NO SPECIAL STATUS
1 OR 2 SERVANTS	2-5 SERVANTS	1 OR NO SERVANTS
CRUDE SERVANTS	SKILLED SERVANTS	INSOLENT SERVANTS
EXPENSIVE GOODS	CHEAP GOODS	SHODDY GOODS
FEW SERVICES	MANY SERVICES	SERVICE "RIP-OFFS"
NO CARS, LITTLE OR NO COMMUTING	CARS, OPEN ROADS, EASY PARKING	LONG DISTANCE COMMUT- ING, TRAFFIC JAMS
URBAN NEIGHBORHOODS	SUBURBS	SUBURBAN SPRAWL
UNNOTICED POLLUTION	LESS POLLUTION	POLLUTION SENSITIVITY
LIMITED TRAVEL	TOURISM	TOURIST POLLUTION

NEW CLASS AGENDA

EXPANSION OF SIZE OF GOVERNMENT
EXPANSION OF POWERS OF GOVERNMENT
HIGHER CIVIL SERVICE SALARIES
EXPANDED RESEARCH BUDGETS
EXPANDED EDUCATION
CREDENTIALISM
"ACADEMIC FREEDOM"
"CIVIL LIBERTIES"
EGALITARIANISM
BLOCKING ECONOMIC GROWTH
OTHER ATTACKS ON RIVAL ELITES

NEW CLASS IDEOLOGY

1. PERSONAL SELF-FULFILLMENT, HAPPINESS, COMFORT, FUN,
FREEDOM, INDEPENDENCE
2. LIFE MAXIMIZATION, RISK AVOIDANCE
NEAR PACIFISM
HEALTH
SAFETY
ANTI-CREATIVE DESTRUCTION
3. "NATURISM"
ECOLOGY AND ENVIRONMENTALISM
ANTI-INDUSTRIALIZATION
ANTI-MACHINERY
ANTI-TECHNOLOGY
4. ANTI-ORGANIZATION
ANTI-CORPORATION
ANTI-NATION-STATE
LOCALISM
SMALL IS BETTER
5. ANTI-TRADITIONS AND TABOOS
RELIGION
SEX
FAMILY
SOCIAL RULES
ADVERSARY CULTURE
6. INTERNATIONAL DOUBLE STANDARD

Appendix B

A MINI-SCENARIO IN WHICH THE LUNAR COMMAND BECOMES THE MAJOR WAR-DETECTING ORGANIZATION

In the year 2000, as part of the "millennium celebrations," the Americans, the Russians, and the Chinese agreed to install a cooperative lunar military command headquarters in order to assure its survivability; 45 percent of the costs were borne by the Americans and their allies, 30 percent by the Soviet group and 25 percent by the Chinese. The lunar complex was large and very elaborate and by 2007 had cost about \$150 billion. After about 10 years the cooperative spirit which had attended its earlier development began to disintegrate but it was not feasible to separate the complex into completely separate functioning sections for each nation, though an attempt was made to do this partially. Still the lunar inhabitants (who were composed of Russians, Americans, Chinese, Japanese, French, and Germans) tended to work together quite well indeed. The members of this lunar group had come to like and appreciate each other--a relationship which could not be dissolved by "orders" from earth. Moreover in their relationship they strongly preferred to emphasize a non-military orientation--only partly because it would improve their security.

A renewed 3-way arms race among the Americans, the Russians and the Chinese, started even before the lunar installation was completely operational, and after 2010 each power started putting up many military satellites. At one point in the year 2018 the Soviets and the Chinese began shooting down each other's satellites. By chance or error (or possibly deliberately) a few American satellites were also destroyed. The Americans,

fearing the worst, retaliated and the situation deteriorated rapidly into an extended space war as satellites were shot down both openly and clandestinely. The three nations started to build and deploy many more military satellites. Although the Chinese were at a relatively great economic disadvantage they did manage a significant amount of space defense capability through some uniquely effective technological designs. All three countries understood that if any one of them could get effective control of space first, it could dominate the subsequent space war. The tension grew into a very serious crisis threatening an escalation to a nuclear exchange on earth, and included accusations that the other sides had sent nuclear weapons into orbit. Actually it would not have made much difference, militarily, if they had or not; but there would be ominous strategic and political precedents in breaking the treaty. During the tension an "accidental" launch of a few nuclear weapons did occur (some analysts deemed it a test of resolve). Two small cities in each of the three nations were destroyed as a result of a tit-for-tat retaliation policy. At this point a general paralyzing fear gripped every nation. At first nobody knew quite how to resolve the dead center paralysis, but the status quo had also become intolerable. Luckily at this point the idea of using the services of a new Lunar Command emerged. At unusual speed for such negotiations a tripartite decision was made for each of the belligerents to turn over the bulk of their space defense satellites to control by a department of the Lunar Authority. The Lunar Command, as this peace keeping group was then designated, was put together hastily and given a firing doctrine which could almost certainly destroy any subsequent small attack and probably would be effective against most

big attacks which could be anticipated. Of course, it was not possible to have a high confidence in the latter situation.

The Lunar Command, today, is only a shell of its earlier organization. It served to resolve an enormously dangerous situation and earned a permanent place in history. A decade from now we expect that it will only be a museum to remind us of one of our inherent potential dangers.

Appendix C

THE PROBLEM OF WAR AND OTHER LARGE-SCALE VIOLENCE

Although since World War II, the world has been much preoccupied with war and threats of war, violence and the threats of violence, compared to almost any other period of history it has actually been a relatively non-violent world. War, especially the threat of a large war, increasingly appears to play a smaller role. Compared to the 21 years between World War I and II, 32 years have passed since the end of World War II and few observers feel that a very threatening situation exists or is likely to occur that could soon lead to World War III, or any similar large scale conflict.

Hudson Institute has long had a professional interest in writing scenarios which lead to the outbreak of "World War III." These are useful in order to test various military programs, such as strategic or arms control plans and preparations, and to give analysts, staffs, and Pentagon decision-makers a context in which they can exercise and test tactical and strategic concepts. However, we have found it increasingly difficult to write plausible scenarios for the outbreak of such a war--though not for the evolution of a reasonably intense crisis. The outbreak scenarios we do write almost invariably arise out of intense political crises in central Europe. In many ways this area is somewhat unstable (though it is not a tinderbox). It is also an area in which the interests of the Soviet Union, the United States and the European countries suggest a great reluctance to accept risks of serious escalation rather than to back down during a crisis.

In this appendix we discuss the likelihood and effects of large scale violence or threats of such violence. However, in our scenarios, except for the Great Space War, and its antecedents and aftermath, we have not let space development be strongly affected by war and threats of war.

This will seem quite unreasonable to almost any historian, and to some degree, also to the authors. However, because analysis shows that many wars or threats of war can occur with little effect upon the principal basic long-run trends--and thus the evolution we are trying to depict--it becomes reasonable to ignore most such potential conflicts although they might make the detailed scenarios more interesting (but considerably more difficult to write). Thus in the year 2000 it should not surprise many people to find that a 1975 map of the world was still quite good--that the national boundaries might be unchanged in any major respect. Even the boundary changes from 1950 to 1975 have been mostly the result of internal wars--that is, violent civil wars. The number of regions where future international wars could plausibly occur appear to be decreasing, not increasing--though there are still some sensitive situations--e.g., the Middle East. Thus, it wouldn't surprise us if relatively little violence occurred between 1975 and 2000. It would surprise us, however, if any violence significantly changed either the map of the world or the basic trends of our time. Still, it is clear that the technological potential for violence is increasing rapidly and must be considered. However, the world's tolerance of violence appears to be decreasing and this could lead to important changes in methods of dealing with violence or the threat of violence--at both low and high

levels. If this remains true it should be a very useful trend for the world as a whole.

In the future we do not expect to have any kind of serious world government beyond that already represented by the U.N. Security Council.* Technically the U.N. Charter (in Articles 41 and 42 of Chapter 7)** does give to the Security Council (if they unanimously agree) the power to control violence in the world. Since they seldom agree this power is basically moot.

We are not likely to achieve, voluntarily, a more effective form of world government than this (usually moribund) potential one of the U.N. Security Council. For example, it is almost impossible to think of an effective world legislature that could be acceptable. A one-man one-vote arrangement would be dominated by a struggle between India and China to run the world, a situation which the powerful wealthy nations would not tolerate, much less create. A one-nation one-vote arrangement--or anything similar--would probably be much like the current U.N. assembly,

*The U.N. is seldom thought of as a world government by many people, even though in 1945 the small and medium nations of the world consciously ceded control over many important world operations to the five big powers.

**These articles read as follows:

Article 41. The Security Council may decide what measures not involving the use of armed force are to be employed to give effect to its decisions, and it may call upon the Members of the United Nations to apply such measures. These may include complete or partial interruption of economic relations and of rail, sea, air, postal, telegraphic, radio, and other means of communication, and the severance of diplomatic relations.

Article 42. Should the Security Council consider that measures provided for in Article 51 would be inadequate or have proved to be inadequate, it may take such action by air, sea, or land forces as may be necessary to maintain or restore international peace and security. Such action may include demonstrations, blockade, and other operations by air, sea, or land forces of Members of the United Nations.

which today, even more than when De Gaulle first made the remark, is a "continuing scandal" as far as it purports to be a world government. (Of course, the assembly does perform useful functions, particularly as a forum and as an international debating society.) Finally, few nations would be interested in a bicameral legislature which very likely would unite the worst features of the above two systems. Moreover, almost all complex weighted voting schemes which have been suggested seem to founder on the above considerations or other similar ones.*

* Someone suggested a scheme might work that in effect was one-dollar, one-vote; that this might be acceptable seems quite dubious. However, it would have the great virtue of being dominated by the nations of the European Economic Community, the U.S., Japan and to a lesser degree by the Soviet Union; nations in which the real power of the world in fact resides. Any workable legislative arrangements presumably would need to reflect this reality.